

**FINAL
ENVIRONMENTAL IMPACT STATEMENT**

**Alternative Cooling Water Systems
Savannah River Plant
Aiken, South Carolina**



October 1987

U.S. Department of Energy

COVER SHEET

RESPONSIBLE AGENCY: U. S. Department of Energy

ACTIVITY: Final Environmental Impact Statement, Alternative Cooling Water Systems at the Savannah River Plant, Aiken, South Carolina.

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ABSTRACT: The purpose of this Environmental Impact Statement (EIS) is to provide environmental input into the selection and implementation of cooling water systems for thermal discharges from the K- and C-Reactors and from a coal-fired powerhouse at the Savannah River Plant. The Savannah River Plant is a major U.S. Department of Energy (DOE) installation for the production of nuclear materials for national defense. This EIS addresses the potential environmental consequences of constructing and operating once-through and recirculating cooling towers for the K- and C-Reactors; increased pumping to a raw water basin and direct discharge to the Savannah River for a coal-fired powerhouse; and no action. The potential environmental consequences assessed include effects on air and water quality, ecological systems, archaeological resources, endangered species, and wetlands.

PREFACE

The purpose of this Environmental Impact Statement (EIS) is to provide environmental input into the selection and implementation of cooling water systems for thermal discharges from K- and C-Reactors and from a coal-fired powerhouse in the D-Area at the Savannah River Plant (SRP); the Plant is a major U.S. Department of Energy (DOE) installation for the production of nuclear materials. Implementation of cooling water systems for these facilities is needed for compliance with the State of South Carolina Class B Water Classification Standards and Consent Order (84-4-W), dated January 3, 1984, and amended August 27, 1985, and August 31, 1987, between DOE and the South Carolina Department of Health and Environmental Control (SCDHEC).

K- and C-Reactors, which are operating production reactors, discharge their cooling water directly to Pen Branch and Four Mile Creek, respectively. The onsite coal-fired powerhouse in D-Area discharges cooling water from cooling-system condensers into an excavated canal prior to discharge to Beaver Dam Creek. These facilities have been in operation since their construction in the 1950s.

On January 1, 1984, SCDHEC issued a National Pollutant Discharge Elimination System (NPDES) permit (Number SC0000175) for the Savannah River Plant. In this permit, the cooling water discharge limitations included a temperature limitation in onsite streams (i.e., onsite streams are not to exceed 32.2°C; in addition, the effluent must not raise the temperature of the stream more than 2.8°C above its ambient temperature) rather than in the Savannah River as previously permitted by EPA. To achieve compliance with these limitations, DOE and SCDHEC entered into a Consent Order (84-4-W) on January 3, 1984, that temporarily superseded the temperature requirements in the NPDES permit and identified a process for attaining compliance. Major elements of this process included a DOE agreement to complete a comprehensive study of the thermal effects of major SRP thermal discharges, the submittal of a thermal mitigation study, and the selection and implementation of cooling water systems.

On October 3, 1984, DOE submitted its Thermal Mitigation Study to SCDHEC. This study describes the cooling water systems that could be implemented for K- and C-Reactors and the D-Area coal-fired powerhouse to achieve compliance with Federal and State water quality standards.

A Notice of Intent to prepare this EIS was published in the Federal Register on July 29, 1985 (50 FR 30728). That notice solicited comments and suggestions from interested agencies, organizations, and the general public for consideration in preparing the EIS. The preliminary scope was included in the Notice of Intent.

Comments were received by mail and at the scoping meeting held in Aiken, South Carolina on August 19, 1985. Written comments were received until August 31, 1985.

In response to the Notice of Intent, 12 individuals, organizations, and governmental representatives provided comments to assist in the preparation of this EIS. Appendix H includes the issues raised during the scoping process and cross-references to the appropriate Draft EIS chapter or appendix.

As part of the scoping process, DOE invited interested parties to comment on its preliminary determination of reasonable alternatives to be considered in the environmental impact statement (i.e., once-through and recirculating cooling towers for K- and C-Reactors, and increased pumping to the raw water basin for the D-Area powerhouse). Because DOE received no comments on this preliminary determination, it has identified these, in addition to direct discharge of D-Area cooling water to the Savannah River and "no action" (required by the Council on Environmental Quality for implementing the National Environmental Policy Act), as the reasonable alternatives that it will consider in detail in this environmental impact statement.

On March 28, 1986, DOE began the public distribution of the Draft EIS to all interested individuals, agencies, and groups for review. Also on March 28, 1986, a notice in the Federal Register (51 FR 10652) announced the availability of the Draft EIS and a 45-day review/comment period on the document from March 28 to May 19, 1986. DOE conducted public hearings in Aiken, South Carolina, on April 30, 1986.

During the 45-day comment period, DOE received 27 statements and comment letters on the Draft EIS. DOE also received three comment letters after May 19, 1986.

Many of these comments have led to revisions in this Final EIS. Appendix J contains the comments received during the public comment period and DOE's responses to these comments.

In this Final EIS, changes from the draft are indicated by vertical lines in the margin of each affected page. Minor typographical and editorial corrections are not identified. Changes that are the result of public comments are identified by the specific comment numbers that appear in Appendix J. A change that is the result of an error (typing error, etc.) in the draft is identified with the letters "TE," and one made to clarify or expand on the draft statement is identified with the letters "TC." Those changes in this Final EIS that are the result of a public comment are identified by an alphanumeric marginal notation (e.g., AA-1); these notations refer to comments in Appendix J. The responses to these comments in Appendix J also provide additional information and clarification.

In this Final EIS, Chapters 2 and 4 and Appendixes B, C, D, and G have the most changes. Appendix I has been added to provide a detailed discussion of the feasibility of using cooling water discharges from K- and C-Reactors for agricultural and aquacultural uses, industrial applications, direct power generation, and ethanol production. In addition to these changes, the order in which the alternatives and subsequent actions/impacts for each reactor are presented have been revised (i.e., discussions of K-Reactor alternatives now precede those of C-Reactor) because the construction of an alternative for K-Reactor would precede the construction of a C-Reactor alternative. No change bars are used for the new Appendix I, the preface, the summary, and for the reordering of the K- and C-Reactor alternatives.

Since the completion of the Thermal Mitigation Study and the Draft EIS, further design evaluations and studies have been performed to determine optimal performance parameters and to achieve lower costs. These evaluations and studies have indicated that, in several areas, optimization of performance

and cost savings can be realized in the construction and operation of once-through towers without introducing major changes in the nature or magnitude of the environmental impacts. These areas include the consideration of gravity-feed versus pumped-feed towers, natural-draft versus mechanical-draft towers, and a chemical injection system for either dissipation or neutralization of chlorine biocide versus holding ponds (and their sizing). Similarly, these evaluations and studies have also led to the development of thermal performance criteria that, when incorporated in the final design of a once-through cooling-tower system, would reduce the potential for cold shock (i.e., reduce the difference between ambient stream temperatures and stream temperatures when the cooling water is being discharged) to fish. In addition, substantive information regarding the biological effects of cooling tower operations has been included in Chapter 4 of this Final EIS.

Since the publication of the Draft EIS, the U.S. Fish and Wildlife Service (FWS) has reclassified the American alligator from "endangered" to "threatened due to similarity of appearance" because the species is no longer biologically endangered or threatened throughout its range (52 FR 107: 21059-21064). The "threatened due to similarity of appearance" status ensures against excessive taking of the alligator and continues necessary protection for the American crocodile, a morphologically similar species. References to the American alligator and impacts to it have been deleted from the summary; references have been retained in the other sections, but without mention of its FWS status (see Appendix C for more details on this reclassification).

This EIS was prepared in accordance with the Council on Environmental Quality NEPA regulations (40 CFR 1500-1508) and DOE's NEPA guidelines (45 FR 20694, March 28, 1980 as amended), by DOE and by DOE's contractors under the direction of DOE. Methodologies used and sources of information relied upon for analysis are identified in this EIS. In addition, available results of ongoing studies have been used.

Referenced material in the EIS is available for review in the U.S. Department of Energy's Public Reading Room, located at the University of South Carolina's Aiken Campus, Aiken, South Carolina, and the Freedom of Information Reading Room, Room 1E-190, Forrestal Building, 1000 Independence Avenue, S.W., Washington, D.C.

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SUMMARY

PURPOSE

The U.S. Department of Energy (DOE) has prepared this final environmental impact statement (EIS) to address the environmental consequences of the proposed construction and operation of modified cooling water systems for K- and C-Reactors and the D-Area coal-fired powerhouse at its Savannah River Plant (SRP) in accordance with Section 102(2)(C) of the National Environmental Policy Act (NEPA) of 1969, as amended, and to provide input into the selection and implementation of such systems. On March 28, 1986, a Federal Register notice (51 FR 10652) announced the availability of the draft EIS and established a 45-day review/comment period on the document, from March 28 to May 19, 1986. On April 30, 1986, DOE conducted public hearings in Aiken, South Carolina. In its preparation of this final EIS, DOE has considered the comments that were submitted by government agencies, private organizations, and individuals during the public hearing and review/comment period. This final EIS incorporates the comments on the draft EIS, DOE's responses, and modifications made as a result of these comments. The major comments received at the public hearings and during the comment period fell into the following categories:

- Alternative uses of cooling water for various agricultural, aquacultural, and power production
- More detailed design analysis and thermal performance data for cooling towers
- Present-worth cost analysis of cooling towers
- Inclusion of predictive biological information similar to that required by Section 316(a) of the Clean Water Act, along with a Habitat Evaluation Procedure (HEP) analysis
- Impact of chlorination/dechlorination and corrosion-inhibiting compounds on the aquatic environment

NEED

The major sources of thermal effluents at the Savannah River Plant are the cooling water discharges from production reactors and the D-Area coal-fired powerhouse. Two of the production reactors, K- and C-Reactors, discharge their cooling water directly to Pen Branch and Four Mile Creek, respectively. The coal-fired powerhouse in D-Area normally discharges cooling water from cooling-system condensers into an excavated canal that flows into Beaver Dam Creek. At present, the discharges from these three facilities do not meet the temperature limits specified in the State of South Carolina's Class B water classification standards.

DOE must implement cooling water systems for the thermal discharges from K- and C-Reactors and the D-Area coal-fired powerhouse to comply with both the South Carolina Class B water classification standards [as contained in the

renewed NPDES permit (Number SC0000175)] and a Consent Order (84-4-W), dated January 3, 1984, and amended on August 27, 1985, and August 31, 1987, between DOE and the State of South Carolina Department of Health and Environmental Control (SCDHEC). The Consent Order contains a compliance schedule for the completion of NEPA documentation and the construction and operation of cooling water systems to attain the Class B water classification standards, subject to the appropriation of funds by Congress. As stated in the NPDES permit, cooling water discharge temperature limits for K- and C-Reactors and the D-Area powerhouse are not to exceed an instream temperature of 32.2°C and the effluent must not raise the temperature of the stream more than 2.8°C above its ambient temperature unless the existence of a balanced biological community can be maintained through evidence provided by a Section 316(a) Demonstration study.

PROPOSED ACTION

The proposed action considered in this environmental impact statement is the construction and operation of cooling water systems for K- and C-Reactors and the D-Area powerhouse to attain compliance with the State of South Carolina's Class B water classification standards. DOE's preferred alternatives are to construct and operate once-through cooling towers for K- and C-Reactors, and to implement increased flow with mixing for the D-Area coal-fired powerhouse. Because the discharge temperatures of cooling water from these preferred alternatives will at times raise the ambient stream temperatures by more than 2.8°C, DOE will conduct Section 316(a) demonstration studies to determine whether a balanced biological community can be maintained.

ALTERNATIVES

DOE initially identified 22 possible alternative cooling water systems that could be implemented for K- and C-Reactors and four alternatives for the D-Area powerhouse. Using a structured screening process, DOE then identified those alternatives that would be reasonable to implement; the screening process and alternatives were documented in a Thermal Mitigation Study, which was submitted to SCDHEC on October 3, 1984. Based on the information contained in its Notice of Intent to prepare this EIS and the comments received during the public scoping period, DOE identified the cooling water alternatives that are considered in detail in this EIS.

Since the completion of the Thermal Mitigation Study and the Draft EIS, further design evaluations and studies have been performed to determine optimal performance parameters and to achieve lower costs. These evaluations and studies have identified several areas in which optimization of performance and cost savings can be realized in the construction and operation of cooling towers without introducing major changes in the nature or magnitude of the environmental impacts. These areas include the consideration of gravity-feed versus pumped-feed towers, natural-draft versus mechanical-draft towers, and a chemical injection system for either dissipation or neutralization of chlorine biocide versus holding ponds (and their sizing). Similarly, these evaluations and studies have also led to the development of thermal performance criteria that, when incorporated in the final design and operation of a cooling-tower system, would reduce the potential for cold shock (i.e., reduce the difference

between ambient stream temperature and stream temperature when the cooling water is being discharged) to aquatic organisms.

The alternatives considered in this EIS for K- and C-Reactors are the construction and operation of once-through cooling towers, the construction and operation of recirculating cooling towers, and the continuation of direct discharge - or no action [as required by the Council on Environmental Quality for implementing the procedural provision of the National Environmental Policy Act (40 CFR 1502.14)]. The alternatives considered for the D-Area coal-fired powerhouse are to increase the inlet water flow with mixing to the D-Area raw-water basin, and mix raw-water basin overflow with the cooling water discharge; to construct a new pipeline to enable a direct discharge to the Savannah River; and to continue the present operation - or no action. None of the three alternatives considered for the K- and C-Reactors would comply with all temperature limits of the South Carolina Class B water classification standards, as contained in the renewed NPDES permit ΔT (e.g., at the point of discharge). However, DOE believes that Section 316(a) studies will indicate that balanced biological communities can be maintained in the receiving stream systems under either the once-through cooling tower or recirculating cooling tower alternative. If the preferred cooling system alternative for K- and C-Reactors (i.e., once-through cooling towers) is judged not acceptable by the South Carolina Department of Health and Environmental Control, DOE may select the recirculating cooling tower alternative in order to meet the conditions of the NPDES permit.

AFFECTED ENVIRONMENT

The Savannah River Plant is a 780-square-kilometer (192,741-acre), controlled-access area near Aiken, South Carolina. This major DOE installation was established in the early 1950s for the production of nuclear materials for national defense. Six principal tributaries to the Savannah River are located on the Plant. Five of these streams have received thermal discharges from SRP cooling water operations. At present, Beaver Dam Creek, Four Mile Creek, and Pen Branch receive direct thermal discharges from the D-Area coal-fired powerhouse, C-Reactor, and K-Reactor, respectively.

The Plant is bordered on the southwest by the Savannah River, which it parallels for about 16 kilometers. About 10,000 acres of the Savannah River swamp forest lie on the Plant from Upper Three Runs Creek to Steel Creek. Three breaches in a natural levee between the swamp system and the Savannah River allow water from Steel Creek, Four Mile Creek, and Beaver Dam Creek to flow to the river. The combined discharges of Steel Creek and Pen Branch enter the river near the southeastern corner of the Plant. During periods of flooding, the Savannah River overflows the levee and floods the entire swamp area, leaving only isolated islands.

The Savannah River downstream of Augusta, Georgia, is classified by the State of South Carolina as a Class B waterway, suitable for agricultural and industrial use, the propagation of fish, and, after treatment, domestic use.

The Savannah River Plant currently withdraws a maximum of 37 cubic meters per second, primarily for cooling production reactors and the D-Area coal-fired powerhouse. Almost all of this water returns to the river via SRP streams. The temperature of water discharged from the reactors normally ranges between 45° and 65°C above ambient.

The thermal discharges from K- and C-Reactors have changed Pen Branch and Four Mile Creek from single-channel, meandering streams to wide, multichannel, braided systems flowing within partially vegetated floodplains. Where the streams enter the swamp, eroded material has been deposited, and deltas have formed and continue to increase in size. An estimated 1817 acres of wetlands have been adversely affected by the K- and C-Reactor thermal discharges. The estimated average annual loss of wetlands between 1975 and 1985 was about 54 acres.

Few aquatic organisms are found in the thermal areas of Pen Branch and Four Mile Creek. The thermal discharges prevent aquatic species from inhabiting the streams while the reactors are operating. Fish spawning in the streams and deltas is restricted.

Water intake withdrawal from the Savannah River for K- and C-Reactors causes annual estimated entrainment losses of about 26.9×10^6 fish eggs and larvae. These losses represent approximately 11 percent of the fish eggs and larvae passing the intake canals during the spawning season. In addition, estimated impingement losses of about 5885 fish occur annually.

Low fish densities and high water levels in portions of Four Mile Creek, Pen Branch, and the Savannah River swamp limit the value of these areas for foraging by the endangered wood stork. No other threatened or endangered species or critical habitat would be affected by the proposed alternatives for K- and C-Reactors.

The operation of the D-Area coal-fired powerhouse results in a withdrawal of about 2.6 cubic meters of water per second from the Savannah River and thermal discharges to Beaver Dam Creek. These discharges meet the State of South Carolina's Class B water classification standard of a maximum instream temperature of 32.2°C except during occasional periods from May through September, when water temperatures can be as high as 34°C under extreme conditions. The discharges from the D-Area powerhouse also fail to meet the Class B water classification standard of a maximum stream temperature rise over ambient of 2.8°C .

The endangered wood stork uses areas of Beaver Dam Creek and its delta for foraging during the summer.

Water withdrawal from the river for the D-Area powerhouse causes estimated entrainment losses of about 2.0×10^6 fish eggs and larvae and estimated impingement losses of about 1718 fish annually.

ENVIRONMENTAL CONSEQUENCES

No action - the once-through direct discharge of cooling water from K- and C-Reactors and the continuation of the thermal discharges from the D-Area powerhouse - would result in discharges that would not meet the State of South Carolina Class B thermal standards. No action would also result in a continuation of the environmental conditions described above as the affected environment. The following sections summarize the environmental consequences of constructing and operating new cooling water systems for K- and C-Reactors and the D-Area coal-fired powerhouse.

K- AND C-REACTOR ONCE-THROUGH COOLING TOWERS (PREFERRED ALTERNATIVES)

The construction and operation of once-through, natural-draft, gravity-feed cooling towers is the preferred alternative for both K- and C-Reactors. Cooling water discharges from the once-through cooling towers would comply with the State of South Carolina Class B water classification standard of a maximum instream temperature of 32.2°C. However, because the effluent discharge would occasionally raise the ambient stream temperatures by more than the maximum allowable change in temperature of 2.8°C, Section 316(a) Demonstration studies would be performed to determine whether balanced biological communities are being maintained. The reduction in the temperature of cooling water discharges as a result of once-through cooling-tower operation and the continued discharge of approximately the same volume of cooling water would increase the available aquatic habitat for fishes and other organisms. Wetland losses, which are currently about 54 acres per year in the delta/swamp, would decrease as a result of reduced discharge temperatures; some revegetation would occur as a result of natural plant succession.

Construction of natural-draft, once-through, gravity-feed towers for K- and C-Areas would adversely affect approximately 60 acres of uplands, less than 1 acre of which is considered to be wetland. Balanced communities containing all biotic categories should develop and remain in the Pen Branch and Four Mile Creek ecosystems. Conditions for all biotic categories would be greatly enhanced in comparison to present conditions. Recolonization of areas that are presently uninhabitable because of excessive temperatures would be expected to occur rapidly.

Zooplankton would become established which would provide food for the development of balanced indigenous macroinvertebrate and fish communities. The maximum predicted summer temperatures in the Pen Branch and Four Mile Creek systems would be within the range tolerated by most, if not all, indigenous zooplankton species. The standing crop, species composition, community structure, and seasonal periodicity should be similar to those of the Pen Branch and Four Mile Creek systems before Plant operation and to those of other natural streams in the region. Cooling-tower discharge flow would not constitute a lethal barrier to the free movement (drift) of zooplankton.

The habitat-formers community would improve with the addition of once-through cooling towers. However, the pattern of recovery is difficult to predict. High flows probably would impede the types of vegetative communities that could develop. Macrophyte development in Pen Branch and Four Mile Creek probably would be restricted to the edges of the islands throughout the lower stream reaches.

The reduced temperature regimes would permit the invasion of some species of aquatic macrophytes and periphyton in parts of the systems that are presently too hot to support plant life. However, rapid water velocities and scoured stream substrates are expected to retard the development of macrophyte communities in the center of the stream channels. In contrast, development of aquatic macrophyte and riparian communities is expected along the stream margins, as well as in the delta areas, where the stream channels are braided and water velocities are reduced.

The combination of above-ambient temperatures and the nutrient-rich river water that is used for reactor cooling should result in higher levels of primary production than would occur without reactor discharge. In addition, much more aquatic habitat would exist with once-through cooling towers than would exist without the reactor discharges, because of the higher water levels. Flow fluctuations during reactor cycling would result in the dewatering and subsequent dessication of large areas of stream bottom during reactor outages. The flow fluctuations probably would result in macrophyte communities dominated primarily by emergent species that could withstand dewatering, although some submerged macrophyte species probably would become established in pools and backwater areas. The dewatering also would impact periphyton communities, causing die-offs during reactor outages. Thus, although conditions with the cooling towers would be improved over existing conditions due to reductions in stream temperatures, flow fluctuations would perturb the ecosystems of the stream corridors and delta areas to some extent and would influence the types of communities that would develop in these areas.

Reduced stream water temperatures in comparison to present conditions would provide a thermal regime in the Pen Branch and Four Mile Creek systems conducive to the establishment of reasonably diverse macroinvertebrate communities. However, elevated temperature regimes and fluctuations in water level could preclude the establishment of some of the more sensitive macroinvertebrate taxa in the streams. The dominant taxa would be expected to shift, with the more thermally-tolerant species being replaced by other species that are less thermally tolerant. Although above-ambient temperatures might produce earlier emergence of many species of aquatic insects, no major adverse impacts should occur. The slightly elevated temperatures could permit multivoltine species of insects (those that complete more than one life cycle per year) to produce one or more additional generations per year, thereby increasing the net annual production of the macroinvertebrate communities. Organisms that can migrate quickly would be favored in Pen Branch and Four Mile Creek, while sessile organisms, as well as taxa that pupate in the water, could experience high rates of mortality during reactor outages. Increased drift would occur during rising and receding water levels, which could result in increased predation and possibly temporary reductions in standing crop. Species that inhabit the stream substrate might not be greatly impacted, except during extended reactor outages, when discharges could be reduced long enough to dry out portions of the stream substrate completely. If large periphyton die-offs are caused by dewatering, secondary production could be reduced temporarily due to the reduced availability of food. However, the standing crop of macroinvertebrates should be sufficient to ensure a good supply of food for higher trophic levels.

The cooling-tower discharge flows should not interfere with the drift or upstream movement of macroinvertebrates, because the predicted maximum temperatures of the plumes would be less than the upper thermal limits of most macroinvertebrate species indigenous to the southeast. No significant farfield impacts should occur, because the water would be near ambient temperature by the time it reaches the Savannah River.

Once-through cooling towers would improve conditions for the fish communities in the Pen Branch and Four Mile Creek systems. The communities in the upper reaches above the reactors are not expected to change substantially from present conditions, because the fish communities in the upper reaches of SRP

tributary streams appear to be stable and not significantly affected by reactor operations. Reproductive activities of all indigenous fish species should be improved over present conditions by implementation of this alternative; growth should be enhanced by the increased productivity resulting from the slight temperature elevation and nutrient loading from Savannah River water pumped through the systems. Final design and operation of the cooling-tower systems would comply with the temperature shock limits proposed by the U.S. Environmental Protection Agency (EPA) for the protection of all warm-water fishes that could occur during a winter shutdown in Pen Branch or Four Mile Creek. Maximal absolute temperatures and fluctuations therein should not block fish migration. Accordingly, the entire Pen Branch and Four Mile Creek systems should be available for fish habitation and reproduction; the free movement of fishes between the stream headwaters and the Savannah River should not be inhibited by reactor operations at any time during the year. The thermal discharge flows should not block fish migration or exclude fish from any part of the ecosystems. Annual entrainment (26.9×10^6 fish eggs and larvae) and impingement (5885 fish) losses are estimated to be about the same as those estimated for current operations.

The implementation of once-through cooling towers with their associated high flow rates, water depths, and lengthy reactor cycles would minimize the availability of preferred foraging habitat of the endangered wood stork.

Air quality impacts, including fogging and icing, elevated visible plumes, and total-solids (drift) deposition would be negligible. The construction of the towers would disturb one known prehistoric archaeological site that has been determined to be "not significant" by the State Historic Preservation Officer.

Current radiological releases, which would continue with the implementation of the once-through cooling-tower alternatives, consist of remobilized radionuclides in the Pen Branch and Four Mile Creek streambed systems, and radionuclides (principally tritium) from small process-water leaks into the cooling water of the reactors' heat exchangers and releases into process sewers. The operation of once-through cooling towers would not produce any significant changes in the remobilization of radionuclides in streambeds because the rate of cooling water discharged from the towers would remain essentially the same as that for current operations. The operation of once-through cooling towers would result in an annual release of about 100 additional curies of tritium to the atmosphere because of cooling water evaporation, and a corresponding reduction of about 100 curies that had been released to the streams. The operation of once-through cooling towers would result in a total reduction in the maximum individual effective whole-body dose of about 2.3×10^{-4} millirem per year, and a decrease in the total collective effective whole-body dose to the 80-kilometer regional population and downstream water consumers of about 5.5×10^{-2} person-rem per year. These radiological dose changes are extremely small when compared to existing operations and to year-to-year variations in natural background radiation; doses would remain within all applicable requirements and standards.

The estimated present worth for the once-through natural-draft cooling tower at K-Reactor with gravity feed would be approximately \$43 million, including production losses (\$41.4 million without production losses). Estimated annual operating costs would be \$6.4 million. Preliminary design studies suggest a 0.2-percent annual average loss of reactor power attributable to the operation

of a once-through tower system in comparison to the No-Action alternative. In addition to construction and operation costs, the estimated cost to conduct a Section 316(a) Demonstration study would be \$1.25 million. Construction would require about 36 months, after a 9-month lead design period.

The estimated present worth for the once-through, natural-draft, gravity-feed cooling tower at C-Reactor would be approximately \$44 million, including production losses (\$42.4 million without production losses). The estimated annual operating cost would be \$6.4 million. The construction would require 36 months following a 9-month design phase. Reactor power could be expected to drop by 0.2 percent due to the operation of the once-through system in comparison to the No-Action alternative. As with K-Reactor, C-Reactor would require an additional \$1.25 million dollars for a Section 316(a) Demonstration study.

K- AND C-REACTOR RECIRCULATING COOLING TOWERS

The construction and operation of recirculating cooling towers for K- and C-Reactors would reduce thermal effects to Pen Branch and Four Mile Creek while reducing the current discharge (flow) rates by about 90 percent. Wetland losses, estimated to be about 54 acres per year as a result of delta expansion, would essentially cease, and the process of natural plant succession would occur in the area currently affected by thermal discharges. An estimated 1500 acres could be reestablished under this alternative. An estimated 110 acres of uplands would be adversely affected by construction of recirculating cooling towers for K- and C-Reactors. No wetlands would be affected by construction.

Balanced communities containing all indigenous species in all biotic categories should develop and remain in all natural portions of the Pen Branch and Four Mile Creek ecosystems following the implementation of recirculating cooling-tower systems for K- and C-Reactors. Predicted maximum water temperatures in the immediate discharge area would not exceed 30°C and, therefore, would be below the maximum of 32.2°C required for Class B waters of the State. However, the other temperature criterion for Class B waters (maximum temperature increment of 2.8°C above ambient) would be exceeded occasionally by a small margin in the immediate discharge area and to a decreasing extent as far downstream as the Pen Branch delta. Accordingly, a Section 316(a) Demonstration study would be conducted to determine if balanced biological communities would be maintained. In addition to temperature mitigation, flow in the creek system would be reduced to levels typical of small streams in the SRP region; these levels should be conducive to recolonization by habitat formers, macroinvertebrates, and fish.

Conditions for all biotic categories should be greatly enhanced following implementation of this alternative in comparison to present conditions. Recolonization of areas within the Pen Branch and Four Mile Creek systems that are presently uninhabitable because of excessive temperatures and flows would occur rapidly. Furthermore, an analysis of the temperature and flow requirements of the representative and important species indigenous to the creek systems has determined that these species should not be affected adversely by the slightly higher-than-ambient temperatures and lower flows resulting from reactor operations.

Following implementation of recirculating cooling-tower systems, a zooplankton community should become established in the study area, which would provide food for the establishment of balanced macroinvertebrate and fish communities. The maximum predicted temperatures in the Pen Branch and Four Mile Creek systems would be within the range tolerated by most, if not all, indigenous zooplankton species; accordingly, the heated discharge should cause no appreciable harm to the zooplankton community. The standing crop of zooplankton should be enhanced by the relatively slight temperature elevation and standing crop, species composition, community structure, and seasonal periodicity should be similar to those present before SRP operation and to those of other natural streams in the region. Cooling-tower blowdown flow would not constitute a lethal barrier to the free movement (drift) of zooplankton.

The habitat-formers community should improve significantly with the implementation of recirculating cooling-tower systems at K- and C-Reactors. Following the implementation of the systems, reactor discharges would be reduced from approximately 11.3 cubic meters per second to about 1 cubic meter per second. The reduced discharge would result in substantial reductions in stream width, depth, and water velocity in comparison to present conditions. Reduced water velocities would decrease the erosion rate of the stream channels in the upper and mid-stream reaches and would be more conducive to the retention of logs and other organic debris in the stream channels, providing structure for aquatic macroinvertebrates. Lower stream temperatures, coupled with reduced stream velocities, would permit the invasion of aquatic macrophytes into the stream channels, and would also permit the establishment of riparian vegetation in what are presently the high water channels of Pen Branch and Four Mile Creek. Aquatic habitat in the delta areas should differ somewhat from that upstream. At present, water flows through the deltas in a series of shallow braided channels. With reduced discharge, most of the flow should follow the paths of the original stream channels, but some water could flow through one or two of the deeper side channels that have been cut through the deltas. This, coupled with the more gradual stream gradient of the deltas, would probably result in lower velocities than would exist upstream. The delta areas should provide prime habitat for many species of aquatic and semiaquatic macrophytes, which in turn would provide habitat for species of macroinvertebrates that prefer slow-moving streams and dense stands of macrophytes.

Following implementation of the recirculating alternative, diverse and productive macroinvertebrate communities should develop in Pen Branch and Four Mile Creek. The newly established communities would, in turn, provide food necessary for the establishment of balanced indigenous fish communities. The species composition of the stream corridors should be somewhat similar to that of the unimpacted headwater portions, although differences would exist due to a more open canopy and to greater stream discharge volumes from reactor operations. Increased light availability would result in systems that are more autochthonous. Thus, macroinvertebrate species that utilize periphyton or macrophytes as food should be expected to be more abundant. As macrophyte beds become established, macroinvertebrate species that are commonly associated with these beds should increase in abundance. The dominant taxa would be expected to shift, with the more thermally-tolerant species presently occurring being replaced by other species that are less thermally tolerant.

A recirculating cooling-tower system would improve the thermal regimes of Pen Branch and Four Mile Creek over existing conditions to within the range of temperatures tolerated by most, if not all, indigenous macroinvertebrate species. Although the relatively slight increases in temperatures over ambient could result in the earlier emergence of some species, no significant adverse impacts should occur, and the potential for cold shock would not exist during reactor outages in the winter. Thus, the cooling-tower blowdown should cause no appreciable harm to the macroinvertebrate communities. Indeed, the standing crop of macroinvertebrates in the streams should be enhanced by the relatively slight elevations in temperature, due in part to an expected increase in the standing crop of periphyton and heterotrophs, which would provide more food for many species of macroinvertebrates. In addition, the slightly elevated temperatures could permit multivoltine species of insects (those that complete more than one life cycle per year) to produce one or more additional generations per year, thereby increasing the net annual production of the macroinvertebrate community.

The cooling-tower blowdown flow should not interfere with the drift or upstream movement of macroinvertebrates, because the predicted maximum temperature of the flow is less than the upper thermal limits of most macroinvertebrate species indigenous to the area.

Following implementation of the recirculating cooling-tower alternative, a temperature-restricted zone of passage in the upper stream reaches would no longer exist. Reduced flow should allow fish to reinvade these sections of the stream systems, and should provide spawning and nursery areas for many species.

Reduced temperature and flow conditions should allow indigenous fish species to inhabit the mid- and lower reaches of Pen Branch and Four Mile Creek. The addition of slightly heated and relatively nutrient-rich Savannah River water to the streams via the cooling-tower blowdown could increase primary and secondary production in these areas. Reproductive success of indigenous fish species would be improved over present conditions; growth may be possibly enhanced by the increased productivity resulting from the slight temperature elevation and nutrient loading from Savannah River water pumped through the systems.

Final design and operation of the cooling-tower systems would comply with the limits, which are proposed by EPA for the protection of warm-water fishes, of temperature shock that could occur during a winter shutdown in Pen Branch or Four Mile Creek. The entire Pen Branch and Four Mile Creek systems would be available for fish habitation and reproduction; the free movement of fishes between the stream headwaters and the Savannah River should not be inhibited by reactor operations at any time during the year. The thermal discharge flows would not block fish migration or exclude fish from any part of the ecosystems. The areal extent of aquatic habitat would be expected to be reduced from present conditions because of reduced flows, resembling ambient conditions. Annual estimated entrainment (eggs and larvae) losses would be reduced from 26.9×10^6 to 3.9×10^6 , while estimated annual impingement losses would be reduced from approximately 5885 to 853 fish. The implementation of recirculating cooling towers would stop existing high flow rates and elevated water temperatures, thus markedly improving habitat conditions for the endangered wood stork.

Maximum annual total-solids deposition from the recirculating towers would be far below levels that cause reduced vegetation productivity. The same prehistoric archaeological site - which has been determined to be not significant - that would be disturbed by the construction of the once-through towers would be affected by the construction of recirculating towers.

The operation of recirculating cooling towers would result in a calculated decrease of about 0.33 curie of cesium released to the Savannah River each year. For both reactors, the operation of recirculating towers would result in an annual release of about 850 additional curies of tritium to the atmosphere because of cooling-tower evaporation and a corresponding reduction of about 850 curies released to the streams. The reduction in radiocesium that would be remobilized, together with the changes in releases of tritium, would produce a total reduction in the maximum individual effective whole-body dose of about 0.19 millirem per year, and a decrease in the collective effective whole-body dose to the 80-kilometer regional population and downstream water consumers of about 1.1 person-rem per year. These radiological dose changes are extremely small in comparison to existing operations and year-to-year variations in natural background radiation, and doses would remain within all applicable requirements and standards.

The estimated present worth for recirculating cooling towers for K-Reactor is about \$90 million including production losses (\$58 million without production losses); this alternative would require about 42 months to construct after a 9-month design period. Estimated annual operating costs would be \$4.4 million. Reactor power could be expected to drop by 3.7 percent due to the operation of the recirculating system in comparison to the No-Action alternative. In addition, the cost to conduct Section 316(a) Demonstration studies would be approximately \$1.25 million.

For C-Reactor, the estimated present worth, annual operating cost, construction and design period, amount of reactor power lost, and cost to conduct a Section 316(a) Demonstration study for the recirculating system would be the same as those for K-Reactor.

D-AREA INCREASED FLOW WITH MIXING (PREFERRED ALTERNATIVE)

The implementation of increased flow with mixing for the D-Area powerhouse would reduce the thermal effects in Beaver Dam Creek during critical periods (May-September) by temporarily increasing the flow at these times. Balanced communities in all biotic categories presently exist in Beaver Dam Creek and should remain after implementation of this alternative. Predicted maximum water temperatures would comply with the maximum of 32.2°C required for Class B waters of South Carolina. However, the other temperature criterion for Class B waters (maximum change in temperature of 2.8°C above ambient) would be exceeded throughout the stream. Accordingly, a Section 316(a) Demonstration study would be conducted to determine whether a balanced biological community would be maintained.

Increased flow during the summer should increase aquatic habitat and the abundance and diversity of aquatic biota. However, terrestrial wildlife habitat would be reduced and associated wildlife would be displaced temporarily during periods of increased pumping. An estimated 4 acres each of

uplands and wetlands would be inundated temporarily because of intermittent flooding from increased flow.

The increase in pumping probably would cause a temporary increase in the erosion of the stream channel, which could result in reduced primary productivity and reduced populations of some benthic invertebrates. However, the expected erosion and the resulting siltation would equilibrate rapidly under an increased flow regime and biota would be expected to recolonize after the disturbance has ceased.

Following implementation of this alternative, a diverse zooplankton community should remain in Beaver Dam Creek and should not be affected adversely by D-Area powerhouse operation. Rather, increased flow with mixing should enhance the zooplankton communities in the immediate discharge area by eliminating potential exposures to lethal temperatures. The heated discharge should not alter the standing crop, community structure, or seasonal periodicity of zooplankton from those values typical of the receiving water-body segment prior to SRP operation and the thermal plume is not expected to constitute a lethal barrier to the free movement (drift) of zooplankton.

The increased flows and reduced temperatures associated with this alternative should improve the habitat-formers community in Beaver Dam Creek. Scouring due to the increased flow would adversely affect primarily the upper reaches of the stream where, at present, macrophytes do not occur because of high water velocity and turbidity. The habitat-formers community in the delta and swamp areas should not be impacted significantly by increased flows because fluctuations of flow and increases in current velocity through these areas would not be as rapid or severe as those upstream.

Implementation of this alternative should not result in significant changes to the structure and function of the existing macroinvertebrate community, although some minor shifts in the relative abundance of some taxa probably would occur as a result of increased water flows. The increased water velocity could result in temporary increases in the drift rate of some species of macroinvertebrates; however, the macroinvertebrate community should be able to sustain the slightly higher rates of drift and would not be adversely affected. Increased rates of macroinvertebrate drift would provide additional food for higher trophic levels. The rise in water level would inundate the edges of the stream and could result in some increases in the overall amount of aquatic habitat available for colonization. When increased pumping stopped, the water levels should recede gradually and not result in significant stranding of macroinvertebrates.

Increased pumping should not alter the present emergence patterns of insects. The cooler water temperatures that would exist in Beaver Dam Creek during the summer months could result in the addition of a few species of macroinvertebrates that cannot tolerate the present summer temperatures. The macroinvertebrate community should provide the food necessary for the maintenance of a balanced indigenous fish community.

The thermal plume resulting from the D-Area cooling water discharge would not interfere with the drift or upstream movement of macroinvertebrates, if such movement were possible. However, because Beaver Dam is an intermittent stream above the outfall, little, if any, drift or upstream movement is possible.

The temperatures of the thermal plume would not constitute a barrier to either the drift or the upstream movement of macroinvertebrates.

The fish community of Beaver Dam Creek should not suffer appreciable harm from the operation of the D-Area powerhouse following increased flow with mixing. There should be no direct or indirect mortality from excess heat or cold shock. Reproductive success and growth of indigenous species of fish should be similar to present conditions with the implementation of this alternative; growth may be enhanced because the slight warming from the powerhouse discharge results in optimal growth temperatures occurring for more of the year than with ambient conditions. Stream temperature is not expected to block fish migration. Thus, the entire Beaver Dam Creek system would be available for fish habitation; the free movement of fishes between the headwaters of Beaver Dam Creek and the Savannah River would not be inhibited by powerhouse operations at any time during the year.

The increased-flow alternative should not cause significant changes to spawning activities in Beaver Dam Creek. Cooler summer temperatures caused by increased flow and mixing could enhance summer spawning. However, this could be offset by the increased variability of flow and temperature resulting from implementation of this alternative.

Annual estimated entrainment of fish eggs and larvae would increase by about 3 percent (from 2.0×10^6 to 2.06×10^6), while estimated impingement losses would increase from 1718 to about 1831 fish. Estimated temporary wetland disturbances would be about 4 acres during periods when pumping was necessary. The increased flow would probably reduce the availability of foraging sites for the endangered wood stork. There would be no impacts to air quality, noise, release of radionuclides, or archaeological resources due to the implementation of this alternative.

This alternative could be initiated without any capital costs. Annual operating costs would increase by about \$30,000. In addition, the estimated cost to conduct a Section 316(a) Demonstration study is about \$1.25 million.

D-AREA DIRECT DISCHARGE TO THE SAVANNAH RIVER

Discharging effluent directly to the Savannah River would lower water temperatures to ambient levels in Beaver Dam Creek. The removal of the discharge flow would lower water levels greatly in the creek, thereby reducing available spawning and foraging habitat for aquatic organisms. An estimated 1 acre of wetlands and 5 acres of uplands would be adversely affected by the construction of the direct-discharge pipeline to the Savannah River. Small increases in water temperatures would occur within a mixing zone in the Savannah River and the discharge would meet State of South Carolina Class B water temperature classification standards outside the mixing zone.

Entrainment and impingement effects would be the same as those experienced during present operations. The removal of the discharge from the D-Area powerhouse to the creek would greatly degrade the habitat of the endangered wood stork. There would be no impacts on air quality, noise, radiological releases, or archaeological resources.

The construction of the discharge pipeline would require a capital cost of approximately \$14 million and about 22 months to complete. Its operation would increase annual operating costs by about \$50,000 per year.

CUMULATIVE ENVIRONMENTAL CONSEQUENCES

The major cumulative impacts associated with the construction and operation of the cooling water alternatives include surface-water usage, ecological impacts, radiological releases, and air quality impacts.

SURFACE-WATER USAGE

The Savannah River Plant currently withdraws approximately 37 cubic meters per second of water from the Savannah River. Approximately 2.4 cubic meters per second of this withdrawal is consumed, and the remainder is returned to the Savannah River via discharges to onsite streams. Total withdrawal from the Savannah River is currently about 24 percent of the 7-day, 10-year low flow (7Q10), or about 13 percent of the average Savannah River flow.

Construction and operation of once-through cooling towers for K- and C-Reactor would not alter the amount of water currently withdrawn from the Savannah River; however, an additional 1.6 cubic meters of water per second would be consumed as a result of evaporative losses from cooling-tower operation. Construction and operation of recirculating cooling towers would reduce the amount of water withdrawn from the river by about 16.3 cubic meters per second and would result in 1.6 cubic meters of water per second consumed as a result of cooling-tower evaporative losses.

Construction of the direct-discharge system for the D-Area powerhouse would not alter the existing amounts of water withdrawal or discharge. Implementation of the increased-flow-with-mixing alternative, which would require additional withdrawals to meet the 32.2°C State Class B water classification standard, would not result in any additional consumptive water losses because the increased withdrawals associated with this alternative would be returned to the Savannah River via Beaver Dam Creek.

ECOLOGY

The principal cumulative impact of the implementation of alternative cooling water systems for K- and C-Reactors and the D-Area powerhouse would be a reduction in the temperatures of Pen Branch, Four Mile Creek, and Beaver Dam Creek. This temperature reduction would allow successional revegetation of thermally affected areas, improvement in wildlife habitats in comparison to existing conditions, and recolonization of thermally affected streams by fish and other lower trophic levels.

Construction and operation of once-through cooling towers for K- and C-Reactors would maintain approximately the same rates of flow and flow variability (i.e., when the reactors are operating as opposed to when they are not operating) in Pen Branch and Four Mile Creek. Construction and operation of recirculating cooling towers would significantly reduce the rates of flow

in these streams, and also reduce the variations in flow. For the once-through cooling towers, the combined effect of reduced stream temperatures and maintenance of approximately the same flow rates would result in the establishment of a greater amount of aquatic habitat than for the recirculating towers; however, because of the larger flow rates and flow variability associated with the once-through cooling towers, operation of recirculating cooling towers would result in the successional recovery of a greater amount of wetlands.

Because of the difference in the rates of withdrawal of Savannah River water between the once-through and recirculating cooling towers, the estimated cumulative Savannah River Plant annual entrainment and impingement losses resulting from cooling water withdrawal would remain about the same with operation of the once-through cooling towers, and would be reduced to 22.9×10^6 fish eggs and larvae and 5030 impinged fish annually with the operation of recirculating cooling towers. Implementation of the increased-flow-with-mixing alternative for the D-Area powerhouse would result in a slightly greater annual estimated cumulative rate of entrainment and impingement (6.0×10^4 fish eggs and larvae and 113 fish).

The implementation of the cooling water alternatives (i.e., once-through or recirculating cooling towers for K- and C-Reactors, and increased flow with mixing for the D-Area powerhouse) including the direct-discharge alternative for the D-Area powerhouse would affect the endangered wood stork in varying degrees. The implementation of the direct-discharge alternative would result in a loss of foraging habitat for the wood stork due to the removal of discharge flows from Beaver Dam Creek to the Savannah River.

RADIOLOGICAL RELEASES

Radiological doses associated with current SRP operations are within applicable limits and account for less than 0.1 percent of the total annual dose to an average individual within 80 kilometers of the Savannah River Plant. Construction and operation of either once-through or recirculating cooling towers would result in a small decrease in the cumulative radiological doses associated with existing and planned SRP operations and other nuclear facilities within the vicinity of the plant. The reduction in cumulative radiological doses would be greater with the operation of recirculating cooling towers than with the operation of once-through cooling towers because of reduced remobilization of cesium-137.

AIR QUALITY

The operation of either once-through or recirculating cooling towers would increase cumulative solids deposition from drift. Maximum annual total solids deposition would be greater for recirculating cooling towers than for once-through towers, and would be far below levels that cause reduced vegetative productivity.

The operation of either once-through or recirculating cooling towers would also cause minor and temporary reductions in ground-level visibility and infrequent visible plumes and ice accumulations within 0.4 kilometer of the towers.

COMPARISON OF ALTERNATIVES

For K- and C-Reactors, the principal environmental benefits of recirculating cooling towers in comparison to once-through towers would be the reestablishment of a greater amount of wetlands, the reduction in entrainment and impingement losses, and the establishment of a potentially greater amount of wood stork foraging habitat. Recirculating towers for both reactors would cost about \$4.0 million less annually to operate than once-through towers. The principal environmental benefit of the once-through cooling towers comparison to recirculating towers would be the maintenance of existing flow levels in the creeks and deltas, thereby providing more potential aquatic habitat for fish and other aquatic organisms. The present worth cost of the once-through cooling-tower system for both reactors would be approximately \$93 million less than that for recirculating cooling towers.

For the various cooling water alternatives for K- and C-Reactors, the following relative rankings of potential wildlife effects were determined from the Habitat Evaluation Procedures Analysis. Effects to terrestrial wildlife from construction of the once-through and recirculation cooling towers are essentially equal. Small stream fish species benefit more from the recirculation alternative in the upper reaches of the creeks. In the middle and lower stream reaches, species such as the catfish and sunfish benefit more from the once-through alternative. In the deep swamp environment, those fish which are more likely to use the swamp during the spawning period benefit more from the recirculation alternative. In the swamp, wading birds benefit more from the recirculation alternative. Overwintering waterfowl such as the mallard benefit more either from the present SRP operations or from the once-through cooling tower.

For the D-Area powerhouse, the principal environmental benefit of the increased-flow-with-mixing alternative over the direct-discharge alternative would be the maintenance of existing water levels in Beaver Dam Creek, thereby maintaining habitat for the endangered wood stork and other aquatic organisms. It would also avoid adverse impacts to about 1 acre of wetlands and 5 acres of uplands that would result from the construction of the direct-discharge pipeline. There would also be a capital cost savings of about \$14 million initially and about \$20,000 per year thereafter.

Table S-1 summarizes and compares the environmental consequences of once-through cooling towers (i.e., DOE's preferred cooling water alternative), recirculating cooling towers, and the no-action alternative for K- and C-Reactors. In addition, Tables S-2, S-3, and S-4 compare these alternatives, along with the expected natural state of Pen Branch within 15 years if reactor operations cease, for Reaches 1, 2, and 3, respectively, of that stream. The division of the Pen Branch watershed into these reaches was based on the presence of distinct stream gradients. These comparisons were made to assess the potential impacts of the alternatives on discrete reaches and the ability of the entire Pen Branch system to exhibit and maintain a balanced biological community. The following paragraphs describe potential effects of the alternatives on the Pen Branch system. (Similar effects should occur on Four Mile Creek for C-Reactor.)

Table S-1. Comparison of the Impacts of the No-Action Alternative to the Combined Impacts of the Once-Through Cooling Towers (Preferred Alternative) and Recirculating Cooling Towers for K- and C-Reactors (page 1 of 5)

Impacts	No Action ^a	Once-Through Cooling Towers (Preferred Alternative ^b)	Recirculating Cooling Towers ^c
SCHEDULE FOR IMPLEMENTATION	Current	Construction of the system would require 36 months after a 9-month design period.	Construction of the system would require 42 months after a 9-month design period.
PRELIMINARY PRESENT - WORTH (MILLION \$)			
- including production \$0 loss		\$87.0 - \$43.0 K-Reactor - \$44.0 C-Reactor	\$180 - \$90 K-Reactor - \$90 C-Reactor
- excluding production \$0 loss		\$83.8 - \$41.4 K-Reactor - \$42.4 C-Reactor	\$116 - \$58 K-Reactor - \$58 C-Reactor
ESTIMATED OPERATING COST (MILLION \$ PER YEAR)	\$12.4 - \$6.2 K-Reactor - \$6.2 C-Reactor	\$12.8 - \$6.4 K-Reactor - \$6.4 C-Reactor	\$8.8 - \$4.4 K-Reactor - \$4.4 C-Reactor
SOCIOECONOMICS	No additional work-force required.	Peak construction work-force of 400 persons and 8 persons for operation.	Peak construction workforce of 600 persons and 12 persons for operation.
WATER WITHDRAWAL AND DISCHARGE RATES	About 22.6 cubic meters per second withdrawn from the Savannah River and discharged to the creeks.	Withdrawal the same as for no action; discharge to the creeks would be about 93% of that for no action or 21 cubic meters per second.	Withdrawal of river water would be about 14% of that for no action or 3.3 cubic meters per second. Discharge to the creeks would be about 10% of that for no action or 2.2 cubic meters per second.
WATER QUALITY	Dissolved oxygen concentrations would continue to be below	State Class B water classification standards for dissolved oxygen concentra-	State Class B water classification standards for

Table S-1. Comparison of the Impacts of the No-Action Alternative to the Combined Impacts of the Once-Through Cooling Towers (Preferred Alternative) and Recirculating Cooling Towers for K- and C-Reactors (page 2 of 5)

Impacts	No Action ^a	Once-Through Cooling Towers (Preferred Alternative ^b)	Recirculating Cooling Towers ^c
	standards intermittently during the summer and suspended solids would be slightly higher than ambient stream levels.	tions would be met. There would be some reduction in suspended solids.	dissolved oxygen concentrations would be met. Dissolved solids concentrations in discharge would be higher than no action or once-through cooling towers because of cycles of concentrations; however, total suspended solids discharged would be greatly reduced.
TEMPERATURE AND FLOW EFFECTS	Water temperature in the creeks would exceed State Class B water classification standards.	State Class B water classification standards for temperature (32.2°C) would be met; Section 316(a) Demonstration studies will be performed for exceedances of 2.8°C rise in ambient stream temperatures.	State Class B water classification standards for temperature (32.2°C) would be met; Section 316(a) Demonstration studies will be performed for exceedances of 2.8°C rise in ambient stream temperatures.
	There would continue to be few aquatic organisms in the thermal areas of the creeks and deltas. A thermal barrier will prevent aquatic movement in both creeks. Fish spawning in both creeks and deltas would remain reduced.	Reestablishment of aquatic fauna and floral communities, spawning, and foraging in presently uninhabited areas. Water levels would continue to fluctuate, causing some stress to aquatic organisms. Thermal barriers eliminated; free movement of aquatic organisms between all parts of streams and river. There would be no potential for cold shock as the	Additional reduction of thermal effects over what would occur with once-through towers except that flooded habitat area for aquatic organisms would be smaller. Most aquatic communities would benefit from reduced flow and decreased magnitude of water level fluctuations. There

Table S-1. Comparison of the Impacts of the No-Action Alternative to the Combined Impacts of the Once-Through Cooling Towers (Preferred Alternative) and Recirculating Cooling Towers for K- and C-Reactors (page 3 of 5)

Impacts	No Action ^a	Once-Through Cooling Towers (Preferred Alternative ^b)	Recirculating Cooling Towers ^c
		Maximum Weekly Average Temperature criteria for winter shutdowns would be met.	would be no potential for cold shock as the Maximum Weekly Average Temperature criteria for winter shutdowns would be met.
ENTRAINMENT/IMPINGEMENT	Water withdrawal would continue to cause entrainment losses of about 26.9×10^6 fish eggs and larvae and the loss of about 5885 fish to impingement annually.	Effects would be about the same as for no action.	Annual entrainment and impingement losses would be reduced to about 3.9×10^6 and 854, respectively.
TERRESTRIAL/WETLAND HABITAT	Annual losses of about 54 acres of wetlands due to discharge temperatures and flows would continue.	Wetland losses would decrease; some revegetation of these areas would occur. 60 acres of uplands would be affected by construction.	Wetland losses would essentially cease and about 1500 acres of wetlands would successively revegetate; about 110 acres of uplands would be affected by construction.
SOLIDS DEPOSITION	None.	Maximum annual total solids deposition rates for each tower would be below levels that cause reduced vegetative productivity.	Maximum annual total solids deposition rates would be higher than for once-through towers but would still be far below levels that cause reduced vegetative productivity.
ENDANGERED SPECIES	Thermally affected areas of Four Mile Creek and Pen Branch	Foraging habitat of the wood stork would be restricted due to	Potential of enhancement of wood stork habitat would be

Table S-1. Comparison of the Impacts of the No-Action Alternative to the Combined Impacts of the Once-Through Cooling Towers (Preferred Alternative) and Recirculating Cooling Towers for K- and C-Reactors (page 4 of 5)

Impacts	No Action ^a	Once-Through Cooling Towers (Preferred Alternative ^b)	Recirculating Cooling Towers ^c
	would remain too hot for fish production and thus of limited forage value for wood stork; no impacts to other threatened or endangered species.	water depth and flow rates. No impacts on other species.	increased due to lower water levels in the creeks and deltas. No impacts on other species.
AIR QUALITY	No impacts.	Temporary small increases in air pollution and dust during construction.	Construction impacts would be similar to those for the once-through towers.
		Ice accumulation, visible plumes, and reduced ground-level visibility impacts from cooling tower operation would be small.	Total frequency of ice accumulation would be higher than once-through cooling tower. Visible plume occurrence would be only slightly more frequent than that of once-through towers. Reduction in ground-level visibility would be less than for once-through towers and would occur over a somewhat wider area.
NOISE	No impacts.	Same as for recirculating towers during construction. Noise levels from operation would be less than for recirculating towers.	Temporary increases in noise levels during construction. Noise from operation less than 70 decibels about 150 meters from towers.

Table S-1. Comparison of the Impacts of the No-Action Alternative to the Combined Impacts of the Once-Through Cooling Towers (Preferred Alternative) and Recirculating Cooling Towers for K- and C-Reactors (page 5 of 5)

Impacts	No Action ^a	Once-Through Cooling Towers (Preferred Alternative ^b)	Recirculating Cooling Towers ^c
ARCHAEOLOGICAL AND HISTORIC SITES	No impacts.	One small nonsignificant prehistoric site near Four Mile Creek would be disturbed during construction.	Same site would be disturbed near Four Mile Creek as with the once-through towers.
RADIOLOGICAL	The cumulative maximum individual effective whole-body dose from SRP and planned facilities would continue at about 3.3 millirem per year. The total collective effective whole-body dose to the regional population and downstream water users would be about 81 person-rem per year; about 0.074 percent of natural background.	Annually, about 100 additional Ci of tritium would be released to the atmosphere and about 100 less Ci of tritium would be discharged to the streams. The maximum individual effective whole-body dose would decrease by 2.3×10^{-4} millirem per year. The total collective effective whole-body dose to the regional population and downstream water users would decrease by 0.055 person-rem per year. The dose changes are very small compared with existing operations and natural background radiation.	Annually, about 850 additional Ci of tritium would be released to the atmosphere and about 850 less Ci of tritium would be discharged to the streams. In addition, a calculated decrease of about 0.33 curie of cesium per year would result from reduced flows. The maximum individual effective whole-body dose would decrease by 0.19 millirem per year. The total collective effective whole-body dose to the regional population and downstream water users would decrease by 1.1 person-rem per year. The dose changes are very small compared with existing operations and natural background radiation.

- No action is defined as the continuation of existing operations of K- and C-Reactors.
- The preferred alternative is to construct and operate once-through gravity feed, natural draft cooling towers) for K- and C-Reactors.
- The alternative is to construct and operate recirculating cooling towers for K- and C-Reactors.

Table S-2. Comparison of Potential Environmental Impacts in Reach 1^a of Pen Branch System (page 1 of 2)

Parameter	Alternative cooling water system			
	No action	Once-through cooling tower	Recirculating cooling towers	Natural stream ^b
Flow (variation), m ³ /sec	11.3 (1-11.3)	10.5 (1-10.5)	1 (0.2-1)	0.03 (natural)
Temperature (°C) Maximum/ T	75/48	32/11	30/6	27/0
Vegetation				
Aquatic	Thermally tolerant algae only.	Limited macrophyte development due to high flows.	Increased macrophyte development, but less available habitat compared to once-through system due to lower flows.	Less available habitat, greater macrophyte species diversity, than recirculating system due to low natural flows.
Riparian	Not present due to high temperatures.	Limited development and distribution due to high flows.	Major increase in available habitats; shrub/herb community; greater species diversity than once-through system.	Highest species diversity; invasion by some nonwetland species.
Macroinvertebrates	Not present due to high temperatures.	Limited abundance and diversity due to flows; early emergence due to T greater than 5°C; stranding could occur due to changing flow rates from reactor operations.	Less available habitat than once-through system, comparable or higher density; greater diversity, reduced potential for early emergence, little chance of stranding due to more stable flows.	Least available habitat due to reduced water volume compared to recirculating system. Highest species diversity, no potential for early emergence.

Table S-2. Comparison of Potential Environmental Impacts in Reach 1^a of Pen Branch System (page 2 of 2)

Parameter	Alternative cooling water systems			
	No action	Once-through cooling tower	Recirculating cooling towers	Natural stream ^b
Fish	Limited utilization by heat-tolerant mosquitofish during reactor outages; no spawning by any species due to excessive water temperatures; however, limited spawning could occur during long shutdowns; not utilized by anadromous and/or riverine species.	Presence of species with high flow tolerance (i.e., minnows, suckers, darters); limited spawning due to fast flow, high gradient, and channelized banks. Limited utilization by anadromous or riverine species.	Maximum development of limited fish habitat and communities; highest fish biomass potential for this reach; higher spawning per unit area than once-through system due to reduced flows. However, access to this reach by fish from downstream reaches 2 or 3 is unlikely due to reduced flows, shallow water depth, and development of dense stands of aquatic vegetation in these reaches.	Less available habitat due to reduced water volume and less spawning success than recirculating system. Access to this reach from downstream reaches 2 or 3 would also be limited due to reduced flows, shallow water depth, and development of dense stands of aquatic vegetation within these lower reaches.
Endangered species (wood stork)	No utilization - lack of suitable habitat.	No utilization - lack of suitable habitat.	No utilization - lack of suitable habitat.	No utilization - lack of suitable habitat.
Waterfowl	No utilization - lack of suitable habitat.	Very low utilization - lack of suitable habitat.	Very low utilization - lack of suitable habitat.	Very low utilization - lack of suitable habitat.

a. Reach 1 comprises approximately 1 percent of the Pen Branch system that is influenced by reactor operation.

b. Stream system expected within a 15-year period after reactor operations cease.

Table S-3. Comparison of Potential Environmental Impacts in Reach 2^a of the Pen Branch System (page 1 of 2)

Parameter	Alternative cooling water system			
	No action	Once-through cooling tower	Recirculating cooling towers	Natural stream ^b
Flow (variation), m ³ /sec	11.5 (1.17-11.5)	10.7 (1.17-10.7)	1.17 (0.2-1.17)	0.17 (natural)
Temperature (°C), Maximum/ T	63/30	32/6	29/3	26/0
Vegetation				
Aquatic	Thermally tolerant algae only.	Limited macrophyte development due to high flows; more available habitat than in Reach 1.	Increased macrophyte development over once-through system, but less available habitat due to reduced flows.	Less available habitat due to reduced flow volume; greater diversity than once-through system.
Riparian	Isolated communities limited to sandbars and stumps due to high flows and temperatures.	Isolated communities limited to sandbars and stumps due to high flow.	Major increase in available habitats; shrub/herb community development; greater species diversity due to reduced flows.	Highest species diversity; invasion by some nonwetland species.
Macroinvertebrates	Minimal use by thermally tolerant species (e.g., oligochaetes and nematodes).	Greater abundance and diversity than in Reach 1; moderate potential for early emergence due to T; stranding possible due to variable flow rates from reactor operations.	Moderate improvement in available habitat over those in Reach 1 due to downstream reductions in flow and temperature. Some potential for early emergence. Little chance of stranding due to more stable flows.	Least amount of available habitat due to reduced water volume; highest species density; no potential for early emergence or stranding.

Table S-3. Comparison of Potential Environmental Impacts in Reach 2^a of the Pen Branch System (page 2 of 2)

Parameter	No action	Alternative cooling water systems		
		Once-through cooling tower	Recirculating cooling towers	Natural stream ^b
Fish	Limited habitat improvement over Reach 1; brief utilization by fish during reactor shutdowns; no spawning during reactor operations; some spawning could occur during long shutdowns.	Moderate improvement in habitat conditions (i.e., reduced temperatures and flows) compared to Reach 1; presence of flow-tolerant species; increased spawning; limited utilization by anadromous species.	Moderate improvement in habitat conditions over those in Reach 1 and once-through systems due to reduced temperatures and flows in upper reach. Reduced utilization and spawning near delta due to reduced flows in shallow depths and development of dense vegetation, which would limit potential access by anadromous and/or riverine species to upper part of Reach 2 and to Reach 1.	Less available habitat and spawning success than recirculating system, limiting access by anadromous and/or riverine species to upper reaches due to reduced flows and dense vegetation.
Endangered species (wood stork)	No utilization due to excessive temperatures and flow.	No utilization due to flows and excessive water depth.	Very low utilization.	Very low utilization due to reduced flows and dense vegetation.
Waterfowl	No utilization.	Moderate utilization in backwater areas.	Moderate utilization.	Moderate utilization.

a. Reach 2 comprises approximately 10 percent of the Pen Branch system that is influenced by reactor operations.

b. Stream system expected within a 15-year period after reactor operations cease.

Table S-4. Comparison of Potential Environmental Impacts in Reach 3^a of the Pen Branch System (page 1 of 2)

Parameter	Alternative cooling water system			
	No action	Once-through cooling tower	Recirculating cooling towers	Natural stream ^b
Flow (variation), m ³ /sec	Highly variable; strongly influenced by Savannah River flows below delta.	Highly variable; strongly influenced by Savannah River flows below delta.	Highly variable; strongly influenced by Savannah River flows below delta.	Highly variable; strongly influenced by Savannah River flows below delta.
Temperature (°C) Maximum/ T	51/14	31/1	29/0	30/0
Vegetation				
Aquatic	Thermally tolerant algae and bacteria only.	Submerged macrophytes limited to edge of delta and lower braided stream area; extensive where present.	Less available habitat than with once-through system; greater abundance due to reduced flow and stable water depth.	Less available habitat than with recirculating system; dense concentrations.
Riparian	Delta - Thermally tolerant herbaceous flora.	Delta - Herbaceous marsh present; should extend into the cypress/tupelo die-off area.	Delta - Herbaceous marsh present but less extensive than once-through system; some shrub species present; old-field species would occur in drier areas.	Delta - Greater development of old-field community; less marsh and shrub vegetation than recirculating system; development of nonwetland species.
	Swamp - Cypress/tupelo community.	Swamp - Cypress/tupelo community.	Swamp - Cypress/tupelo community.	Swamp - Cypress/tupelo community.
Macroinvertebrates	Greater community diversity than in Reach 2; dominated by thermally tolerant species (e.g., oligochaetes and nematodes).	Great increase in diversity and abundance over no action due to temperature reduction; stranding due to variable flows limited to delta area (swamp	Less available habitat but higher quality than with once-through system due to reduced flows; great increase in diversity and abundance over no action; little chance	Less available habitat than recirculating system; similar in abundance and diversity; little chance of stranding due to more stable flows.

Table S-4. Comparison of Potential Environmental Impacts in Reach 3^a of the Pen Branch System (page 2 of 2)

Parameter	Alternative cooling water system			
	No action	Once-through cooling tower	Recirculating cooling towers	Natural stream ^b
Fish	Only thermally tolerant species near delta; brief utilization by fish during reactor shut-downs; limited utilization and spawning by anadromous species in upper swamp due to high temperatures.	flow is regulated by Savannah River); no early emergence expected. Habitat greatly improved over Reach 2; increased spawning success, utilization, and access by anadromous and riverine species due to reduced temperatures.	of stranding due to more stable flows. Reduced utilization and spawning in delta area due to reduced flows, shallow water depth, and development of dense vegetation, which would limit potential access to upper reaches. Habitat for spawning and nursery areas in swamp depends on periodic flooding by Savannah River.	Less available habitat and spawning success than recirculating system due to reduced flow and extensive vegetation in delta area. Swamp utilization similar to that for recirculating system.
Endangered species (Wood Stork)	Very low utilization due to excessive temperatures and flow.	Very low utilization in delta area due to flows.	Increased utilization for feeding due to reduced flows in delta area; this would decrease as vegetation invades.	Limited utilization due to reduced flows in delta area. Decreased use due to vegetation invasion, which would be more rapid than for recirculating system.
Waterfowl	High to moderate utilization, particularly below the delta.	High to moderate utilization of all alternatives due to reduced temperatures near delta.	Moderate utilization; less than with once-through system due to less available habitat from flow reduction near delta and extensive vegetation.	Moderate to low utilization due to less available habitat and less use than with once-through system due to extensive vegetation.

a. Reach 3 comprises approximately 89 percent of the Pen Branch system as utilized for the HEP analysis (Mackey et al., 1987).

b. Stream system expected within a 15-year period after reactor operations cease.

Impacts On Reach 1

Reach 1 extends from the K-Reactor outfall down Indian Grave Branch to its confluence with Pen Branch and on to SRP Road A; it encompasses approximately 1 percent (11 of 1100 acres) of the portion of the Pen Branch system that is influenced by K-Reactor Cooling Water discharges, as utilized for HEP analysis (Mackey et al., 1987). In this reach, the stream is highly channelized and has its highest gradient, water temperatures, and flows.

With the no-action alternative, highly thermally tolerant species of algae would be the only biota to occur, in limited areas. No spawning activity would occur during reactor outages; limited spawning could occur during long reactor shutdowns, but the success of the spawn would be unsure.

With the once-through cooling tower alternative, communities of aquatic and riparian vegetation should develop, but the areal extent, abundance, and species diversity would be limited due to the presence of high and variable cooling water flows. The early emergence of some macroinvertebrate species could occur because of the elevated water temperature; stranding of some macroinvertebrate communities could occur as a result of reactor-induced variations in flow. The fishery community would be limited in size and dominated by species with high flow tolerance (i.e., minnows, suckers, and darters). Spawning by fish would be extremely limited due to fast flow, high stream gradient, and channelized banks. The utilization of Reach 1 by anadromous and riverine species would be limited due to its distance (6 to 8 kilometers) from the Savannah River.

With the recirculating cooling-tower alternative, an increase in the areal extent and diversity of riparian vegetation would occur in comparison with those for the once-through system. An increase in the areal extent of aquatic macrophytes also would occur, but, because of the reduced water flows to be experienced with this alternative, the total available habitat would be reduced. Less habitat would be available for macroinvertebrate communities, but the abundance per unit area would be comparable to that for the once-through system. Species diversity would be greater and the potential for early emergence of macroinvertebrate species would be reduced over that for the once-through system because of reduced temperatures. The more stable water flows would produce little chance of stranding of macroinvertebrates. The reduced flow associated with this system would limit the areal extent of available habitat for fish; however, this habitat would be of higher quality than that for any of the alternatives. This alternative would provide the highest potential standing crop of fish of the alternatives; higher spawning per unit area should occur than with the once-through system. However, access to this region by anadromous or riverine fish species from Reaches 2 and 3 is unlikely due to reduced flows, shallow water depth, and development of dense stands of aquatic vegetation.

The complete cessation of reactor operations (i.e., a return to natural stream conditions) would provide less available habitat for aquatic vegetation and macroinvertebrates than the recirculating cooling-tower alternative due to a further reduction in water flows. Riparian areas would be colonized by some nonwetland vegetation. However, the species diversity of these communities would be the highest of all identified alternatives. No potential would exist for the early emergence of any macroinvertebrate species. Less habitat would

be available for fish, and spawning success would be less than that for the recirculating system due to lower flows. In addition, access to this region by fish from downstream Reaches 2 and 3 would be unlikely due to reduced flows, shallow water depths, and the expected development of dense stands of aquatic vegetation.

The stream gradient and flows of Reach 1 would not provide suitable habitat for the endangered wood stork or for waterfowl with any alternative.

Impacts On Reach 2

Reach 2 extends from SRP Road A to the Pen Branch delta. This reach encompasses approximately 10 percent (110 of 1100 acres) of the Pen Branch system that is influenced by reactor cooling water discharges, as utilized for the HEP analysis (Mackey et al., 1987). In this reach, the stream is wider and less channelized, and has less gradient than in Reach 1; shallow backwaters occur in some areas.

The high flows and temperatures expected in Reach 2 (Table S-3) with the selection of the no-action alternative would allow the occurrence only of isolated communities of riparian vegetation (limited to sandbars and stumps); aquatic vegetation would be limited to thermally tolerant algae. Thermally tolerant macroinvertebrate species would make minimal use of the reach. Only limited improvement in the quality of fish habitat would be expected over the conditions described for Reach 1. Utilization by fish would be limited to brief reactor shutdown periods. No spawning would occur during reactor operations; however, limited spawning could occur during long shutdowns. The high flows and temperatures would preclude the use of this reach by the endangered wood stork and waterfowl.

The once-through cooling-tower alternative would reduce water temperatures below those for no action, but flows would remain high and variable (Table S-3). The high flows would limit riparian vegetation to isolated communities on sandbars and stumps. Limited macrophyte development would occur in backwater areas of reduced flow; more total habitat would be available than in Reach 1. The macroinvertebrate community would have greater species diversity and abundance in comparison to Reach 1. Some early emergence should occur with some macroinvertebrate species, due to elevated temperature; some stranding of portions of the macroinvertebrate community could occur due to reactor-influenced flow variations. A moderate improvement in fish habitat conditions over those in Reach 1 would occur due to downstream reductions in temperature, gradient, depth, and flows; this should provide the greatest occurrence of flow-tolerant species and more moderate spawning activity within the reach. Use of this reach by anadromous species would be limited. The endangered wood stork would not use Reach 2, but limited habitat would probably be available for waterfowl in backwater areas.

With the recirculating cooling-tower alternative, reduced flow and temperature would provide an increase in riparian habitat (i.e., development of a shrub/herb community) and greater species diversity in Reach 2. Reduced flows would also enable greater aquatic macrophyte development to occur in comparison to the once-through alternative; however, less total habitat area would be available. A moderate improvement would occur in habitat available for the macroinvertebrate community, in comparison to that expected in Reach 1 with

this alternative and to the once-through alternative, as a result of reductions in temperature and flow. Early emergence of macroinvertebrate species would not occur. The reduced flows and temperatures would also provide moderate improvement of fish habitat in the upper portions of Reach 2; however, the reduced water flows and the increased development of vegetation in the lower portions of the reach probably would cause reduced use and spawning in the shallow areas of the delta. Access by fish to the upper portion of Reach 2 and to Reach 1 could become limited due to reduced flows and dense vegetation development. Limited use of this reach by the endangered wood stork and waterfowl would occur.

With a complete cessation of reactor cooling water flows (natural stream conditions), the reduced water volumes in the stream would cause further reductions in available habitat for aquatic vegetation, macroinvertebrates, and fish in comparison to the recirculating cooling-tower alternative (Table S-3). However, species diversity of the aquatic and riparian vegetation and macroinvertebrate communities would be greater in areas where habitat is available. There would be no potential for early emergence of any macroinvertebrate species, and reactor-influenced stranding would not occur. The reduced water volumes would cause the present riparian habitat to be colonized by nonwetland species. The reduced flows and increased density of vegetation would limit fish access to the upper reaches of the stream and, thus, limit overall use and spawning. The endangered wood stork would not use Reach 2, but limited use by waterfowl would occur.

Impacts On Reach 3

Reach 3 of the Pen Branch system, as utilized for the HEP analysis (Mackey et al, 1987) extends from the Pen Branch delta approximately 2 kilometers into the Savannah River swamp; it encompasses approximately 89 percent (988 of 1100 acres) of the Pen Branch system. However, approximately 40 percent of this reach is considered to be part of the Savannah River Swamp and, therefore, is not influenced by reactor operations (Mackey et al., 1987). In Reach 3 the stream is highly braided; the gradient is the lowest of all the reaches; sheet flow is prevalent; and water flows are extremely variable, influenced primarily by periodic Savannah River flooding. The following discussion for each alternative considers only the portion of Reach 3 that potentially is influenced by reactor operations.

With the no-action alternative, aquatic vegetation would be limited to thermally tolerant algae and bacteria (Table S-4). Riparian vegetation in the delta probably would consist of thermally tolerant herbaceous flora; in the swamp, the cypress-tupelo community would predominate. The macroinvertebrate community would be more diverse than that in Reach 2, but it would be dominated by thermally tolerant species (e.g., Oligochaetes and Nematodes). Only thermally tolerant fish species would occur in the delta area. Brief use by some species would occur during reactor shutdowns. In the swamp, high temperatures would limit use and spawning by anadromous species. The endangered wood stork would not use Reach 3 with this alternative; however, extensive use by waterfowl should occur, particularly below the delta.

With the once-through cooling-tower alternative, submerged macrophytes should develop, but their distribution would be limited to the edge of the delta and the lower sections of the braided-stream area; in this area, high abundance

would occur. Herbaceous marsh should develop in the riparian areas of the delta, while the cypress-tupelo community would predominate in the swamp. As a result of the large reduction in water temperatures, a substantial increase in macroinvertebrate community diversity and abundance would occur in comparison to the no-action alternative. No early emergence of any species should occur, and stranding due to variable flows would be limited to the delta area because flow in the swamp is influenced strongly by Savannah River flows. Because of lower flows and temperatures, fish habitat should be greatly improved over that present upstream; much greater use and spawning success would occur. Some access to Reach 2 would be available for anadromous and other species. Because of high flows, the endangered wood stork probably would not use this reach for foraging; however, because of lower water temperatures, waterfowl should use the delta area to a greater extent than they would for the no-action alternative.

Less aquatic vegetation habitat would be available with the recirculating cooling-tower system than with the once-through alternative (Table S-4). However, the reduction in flow and the resultant decrease in water depths would provide greater vegetation abundance in the areas of occurrence. In the delta area, herbaceous marsh should occur but in less abundance than with the once-through alternative; shrub species would also be present and old-field species would occur in the drier areas. In the swamp, the cypress-tupelo community would predominate. Less macroinvertebrate habitat would be available than with the once-through system, but the habitat would be of higher quality because of reduced, stable flows. A substantial increase in macroinvertebrate community diversity and abundance would occur, and there would be little chance of stranding due to the more stable flows. Fish use and spawning would be reduced in the delta area as a result of the reduced flow, shallow water depths, and increased densities of vegetation, all of which could also limit access to the upper stream reaches. In the swamp, a high-quality habitat for spawning and nursery functions would occur as a result of the influence of the Savannah River on water levels. Use of the delta area by the endangered wood stork would increase as a result of reduced flows; however, this eventually would decrease as revegetation of the area proceeds. Less habitat would be available in the delta for waterfowl in comparison to the once-through alternative because of flow reduction and the related revegetation of the area.

With a complete cessation of reactor cooling water discharge (natural stream conditions), less habitat would be available for aquatic vegetation than with the recirculating cooling-tower alternative. However, in the available areas, dense concentrations should occur. In the riparian areas of the delta, there would be greater development of an old-field community, with less marsh and shrub vegetation than with the recirculating alternative. In the swamp, the cypress-tupelo community would predominate. Less macroinvertebrate habitat would be available, but community diversity and abundance should be similar to those for the recirculating alternative. There should be little chance of macroinvertebrate stranding due to more stable flows. In the delta area, less fish habitat would be available and spawning success should be less because of reduced flow and revegetation effects that reduce aquatic habitat. However, in the swamp, fish use should be similar to that with the recirculating system. Limited use of the delta area by the endangered wood stork should occur; this would decrease at a more rapid rate than with the recirculating

alternative due to revegetation. There would be less use by waterfowl because revegetation would cause less available habitat.

Table S-5 summarizes and compares the environmental consequences of DOE's preferred cooling water alternative (i.e., increased flow with mixing), direct discharge to the Savannah River, and the no-action alternative for the D-Area powerhouse.

FEDERAL AND STATE REQUIREMENTS

Table S-6 lists the permits and other environmental approvals required for the implementation of cooling water alternatives for K- and C-Reactors and the D-Area powerhouse and the current status of each requirement.

Table S-5. Comparison of the No Impact Alternative to the Impacts of the Increased Flow with Mixing (Preferred Alternative) and Direct Discharge Alternative for the D-Area Coal-Fired Powerhouse (page 1 of 3)

Impacts	No action ^a	Increased flow with mixing (Preferred Alternative)	Direct discharge to Savannah River
SCHEDULE FOR IMPLEMENTATION	Current	Current	Construction of this alternative would require about 22 months.
PRELIMINARY COST CAPITAL (MILLION \$)	\$0	\$0	\$14
ESTIMATED OPERATING COST INCREASE (MILLION \$ PER YEAR)	\$0	\$0.03	\$0.05
SOCIOECONOMICS	No additional work-force required.	No additional work-force required.	Peak construction work force of 40 persons.
WATER WITHDRAWAL AND DISCHARGE RATES	About 2.7 cubic meters per second would continue to be withdrawn from the Savannah River and discharged to Beaver Dam Creek.	Withdrawal and discharge rates would be the same as for no action except when withdrawal and discharge rates each could be as high as 4.0 cubic meters per second to meet the 32.2°C Class B water classification standard.	Withdrawal and discharge rates would be the same as for no action; however, thermal discharge would be directly to the Savannah River. All powerhouse thermal discharges would be removed from Beaver Dam Creek.
TEMPERATURE AND FLOW EFFECTS	Water temperatures in Beaver Dam Creek would continue to exceed the 32.2°C State Class B water classification standard during periods from May through	Water temperatures in the stream would meet the 32.2°C State Class B water classification standard; a Section 316(a) demonstration study will be performed for exceed-	In Beaver Dam Creek, water temperatures would be at ambient levels year-round. In the Savannah River, water temperatures beyond a mixing zone at the discharge point

Table S-5. Comparison of the No Impact Alternative to the Impacts of the Increased Flow with Mixing (Preferred Alternative) and Direct Discharge Alternative for the D-Area Coal-Fired Powerhouse (page 2 of 3)

Impacts	No action ^a	Increased flow with mixing (Preferred Alternative)	Direct discharge to Savannah River
	September; water temperatures would also exceed the maximum ambient stream temperature rise standard of 2.8°C. Concentrations of suspended solids would remain slightly higher than in ambient streams. There would continue to be reduced numbers of aquatic organisms and spawning in the thermally affected areas of Beaver Dam Creek during the warmer months.	ances of 2.8°C rise in ambient stream temperature. Slight increases in suspended solids concentrations would occur during periods of increased flow. No major changes in aquatic fauna or floral communities would be expected to occur except that habitat area would increase during periods of increased flow.	would meet the State Class B water quality classification standard of 32.2°C. Low water levels in Beaver Dam Creek would greatly reduce existing aquatic habitat; however, the absence of thermal stress would allow full use of this habitat by aquatic organisms. Fish spawning would be limited because of reduced habitat. An adequate zone of passage would be present in the river.
ENTRAINMENT/ IMPINGEMENT	Water withdrawal would continue to cause annual entrainment losses of about 2.0×10^6 fish eggs and larvae and the loss of about 1718 fish due to impingement annually.	Increased water withdrawal over that for no action would increase annual entrainment losses by about 6.0×10^4 fish eggs and larvae and the loss of an additional 113 fish due to impingement annually.	Effects would be about the same as for no action.

Table S-5. Comparison of the No Impact Alternative to the Impacts of the Increased Flow with Mixing (Preferred Alternative) and Direct Discharge Alternative for the D-Area Coal-Fired Powerhouse (page 3 of 3)

Impacts	No action ^a	Increased flow with mixing (Preferred Alternative)	Direct discharge to Savannah River
TERRESTRIAL/WETLAND HABITAT	No impacts.	Operation would result in an estimated loss of about 4 acres of wetlands and about 4 acres of uplands.	Construction would result in an estimated loss of about 1 acre of wetlands and 5 acres of uplands.
AIR QUALITY	No impact.	No impact.	No impact.
ENDANGERED SPECIES	The adjacent swamp area would continue to be used by wood storks for foraging. No impact on other endangered species.	Some decrease in wood stork foraging habitat during increased flow periods. No impacts on other species.	Loss of much of the wood stork foraging habitat due to lowered water levels in Beaver Dam Creek. No impacts on other species.
ARCHAEOLOGICAL AND HISTORICAL SITES	No impacts.	One site will be recommended for eligibility for nomination to the <u>National Register of Historic Places</u> . A "no effect" determination issued by the SHPO.	Survey of pipeline area revealed no historic sites.
RADIOLOGICAL RELEASES	No impacts.	No impacts.	No impacts.

a. No action is defined as the continuation of existing operations of the D-Area coal-fired powerhouse.

Table S-6. Required Regulatory Permits and Notifications (page 1 of 2)

Activity/facility	Requirement(s)	Agency	Status
Water			
Cooling water systems construction	Construction permits	South Carolina Department of Health and Environmental Control, Industrial and Agricultural Wastewater Division	To be submitted by September 30, 1988, subject to the appropriation of funds by Congress
	Section 404 permit ^a	U.S. Army Corps of Engineers (COE)	To be submitted prior to construction
	Section 401 certification ^a	South Carolina Department of Health and Environmental Control, Division of Water Quality	Requested by COE as part of the dredge-and-fill permit process
	Section 10 permit for structures in navigable waters ^a	U.S. Army Corps of Engineers	To be submitted prior to construction
	Permit for structures in navigable waters ^a	South Carolina Budget and Control Board	To be submitted prior to construction
Cooling water discharges	NPDES permit	South Carolina Department of Health and Environmental Control, Industrial and Agricultural Wastewater Division	Issued; modification to permit conditions to be made prior to operation of selected cooling water system
Compliance with delta 2.8°C temperature requirement ^b	Section 316(a) (thermal impact) Demonstration	South Carolina Department of Health and Environmental Control, Industrial and Agricultural Wastewater Division	Plans for conducting studies to be submitted within 2 months following project completion
Water withdrawal/water use	Quarterly reporting	South Carolina Water Resources Commission	Routine reports will continue to be submitted
Endangered species	Consultation/biological assessment	U.S. Fish and Wildlife Service	Consultations with FWS completed

Table S-6. Required Regulatory Permits and Notifications (page 2 of 2)

Activity/facility	Requirement(s)	Agency	Status
Fish and Wildlife Coordination Act	Consultation/consideration of fish and wildlife resources	U.S. Fish and Wildlife Service	Consultations with FWS completed
Migratory Bird Treaty Act	Consultation with FWS	U.S. Fish and Wildlife Service	Consultation with FWS completed
Anadromous Fish Conservation Act	Consultation with FWS	U.S. Fish and Wildlife Service	Consultation with FWS completed
Historic preservation	Archaeological survey and assessment	South Carolina Historic Preservation Officer	Surveys and assessments completed; consultation with SHPO completed
Floodplains/wetlands ^c	Assessment and determination	U.S. Department of Energy	Notice published in <u>Federal Register</u> (51 FR 10654) concurrently with notice of availability of the draft EIS on March 28, 1986; determination published after completion of FEIS

a. Applicable to the D-Area coal-fired powerhouse direct discharge alternative.

b. Applicable to once-through cooling-tower alternatives for K- and C-Reactors and the increased pumping alternative for the D-Area coal-fired powerhouse.

c. Refer to Appendix F.

CHAPTER 1

NEED FOR COOLING WATER SYSTEMS AND PURPOSE OF THIS ENVIRONMENTAL IMPACT STATEMENT

The implementation of cooling water systems for major sources of thermal effluents at the Savannah River Plant (SRP) is needed for compliance with the Clean Water Act and a Consent Order (84-4-W), dated January 3, 1984, and amended August 27, 1985, and August 31, 1987, between the U.S. Department of Energy (DOE) and the South Carolina Department of Health and Environmental Control (SCDHEC). The purpose of this environmental impact statement is to address the potential environmental consequences of constructing and operating alternative cooling water systems for thermal discharges from K- and C-Reactors and from a coal-fired powerhouse in D-Area as input to the selection and implementation of such systems.

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1.1 NEED

The Savannah River Plant is a controlled-access area of approximately 780 square kilometers (192,700 acres) near Aiken, South Carolina. It is a major DOE installation established in the early 1950s for the production of nuclear materials for national defense. Plant facilities, which can be characterized as heavy industry, consist of five production reactors (four operational and one in standby status), electrical and steam generating plants, two chemical separations facilities, fuel and target fabrication facilities, research laboratories, and support and administrative facilities.

The major sources of thermal effluents at the Savannah River Plant are the cooling water discharges from the production reactors and an onsite coal-fired powerhouse. Two of the currently operating production reactors, K- and C-Reactors, discharge their cooling water directly to Pen Branch and Four Mile Creek, respectively. The coal-fired powerhouse in D-Area normally discharges cooling water from cooling-system condensers into an excavated canal that flows into Beaver Dam Creek.

The thermal effluent from P-Reactor is cooled by an onsite 2700-acre cooling lake, Par Pond. DOE conducted Section 316(a) and 316(b) studies, as required by the Federal Water Pollution Control Act, as amended (33 USC 1326), and submitted the results of these studies to SCDHEC. On May 14, 1987, SCDHEC concurred with DOE's conclusions that balanced indigenous populations of fish, shellfish, and wildlife presently exist in Par Pond and that the present operations of P-Reactor pose no threat to the continued existence of a balanced indigenous biological community. L-Reactor discharges its cooling water to a 1000-acre cooling lake. Predictive Section 316(a) studies indicating the probable existence of balanced biological communities within and below the cooling lake have been submitted to, and approved by, SCDHEC. The restart of L-Reactor and the cooling lake are discussed extensively in the Environmental Impact Statement, L-Reactor Operation, Savannah River Plant (DOE, 1984a). More detailed discussions of P- and L-Reactors are not within the scope of this EIS.

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A renewed NPDES permit (Number SC0000175) issued by SCDHEC became effective on January 1, 1984, for SRP operations. The purpose of this permit was to regulate the Plant's discharges of wastewater - including cooling water - to surface streams and other water bodies. As stated in the permit, cooling water discharge temperature limits for K- and C-Reactors and the D-Area powerhouse are not to exceed an instream temperature after mixing of 32.2°C; in addition, the effluent must not raise the temperature of the stream more than 2.8°C above its ambient temperature unless the maintenance of a balanced biological community can be determined by a Section 316(a) demonstration study.

To achieve compliance with these temperature limitations, DOE and SCDHEC entered into a mutually agreed-on Consent Order (84-4-W). This order temporarily superseded the temperature requirements in the NPDES permit and established a process for attaining compliance. Key elements of this process required DOE to:

- Complete a "Comprehensive Cooling-Water Study" of the thermal effects of operations at the Savannah River Plant
- Complete and submit a Thermal Mitigation Study to SCDHEC
- Submit and actively support funding requests to accomplish any actions resulting from the Thermal Mitigation Study
- Undertake work on the alternatives approved by SCDHEC, under a schedule to be established in an amendment to the Consent Order, subject to the appropriation of funds by Congress

In compliance with the Consent Order, DOE submitted a Thermal Mitigation Study (DOE, 1984b) to SCDHEC on October 3, 1984; the Comprehensive Cooling-Water Study, Annual Report (Du Pont, 1985) was submitted in July 1985.

TC | On August 27, 1985, DOE and SCDHEC mutually agreed on an amendment to Consent Order 84-4-W of January 3, 1984, that established a compliance schedule for the completion of National Environmental Policy Act (NEPA) documentation by December 31, 1986. This amendment also established an implementation schedule for the start of construction of a selected cooling water system for C-Reactor on or before September 30, 1987, and completion of construction on or before March 31, 1989. The amendment established the date for the start of construction of a system for K-Reactor on or before September 30, 1987, and completion of construction on or before July 31, 1989. The Consent Order also established March 31, 1987, as the date by which DOE must submit a plan of study and an approvable schedule for the implementation of a cooling water system for the D-Area powerhouse. In compliance with the Amended Consent Order, DOE published a Notice of Availability (51 FR 10652) and submitted a copy of the draft environmental impact statement (EIS) to SCDHEC on March 28, 1986.

TC | On October 29, 1986, DOE and SCDHEC mutually agreed that it would be necessary to change the schedule in the Amended Consent Order. DOE requested this change to respond to comments received from SCDHEC and the U.S. Environmental Protection Agency on the draft EIS. On August 31, 1987, DOE and SCDHEC

mutually agreed on a second amendment to the Consent Order, which established a compliance schedule for the completion of NEPA documentation by October 31, 1987. The second amendment also specified that on or before September 30, 1988, DOE must submit plans and specifications to SCDHEC for the K-Reactor mitigation alternative subject to the authorization of and appropriation of funds by Congress. In addition, this amendment established an implementation schedule for the start of construction of a selected cooling water system for K-Reactor on or before February 28, 1990, and completion of construction on or before December 31, 1992. The amended Consent Order also established March 31, 1988, as the date by which DOE must submit a plan for a Section 316(a) demonstration study and an approvable schedule for the implementation of a cooling water system for the D-Area powerhouse. In addition, the amended Consent Order stated that DOE shall notify SCDHEC immediately upon determination that C-Reactor is to restart and propose a timely schedule for construction of its thermal mitigation alternative.

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Implementation of cooling water system alternatives at K- and C-Reactors and the D-Area coal-fired powerhouse is needed for compliance with South Carolina water classification standards [as contained in the NPDES permit (Number SC0000175)], and Consent Order 84-4-W between DOE and SCDHEC.

1.2 PURPOSE

The purpose of this environmental impact statement is to address the potential environmental consequences of constructing and operating cooling water systems for thermal discharges from K- and C-Reactors and from the coal-fired powerhouse in D-Area in compliance with Section 102(2)(C) of the National Environmental Policy Act of 1969, as amended, and to provide input into the selection and implementation of such systems.

The proposed action is to construct and operate cooling water systems for K- and C-Reactors and the D-Area powerhouse to attain compliance with the State of South Carolina's Class B water classification standards. DOE's preferred alternatives are to construct and operate once-through cooling towers for the K- and C-Reactors, and to implement increased flow with mixing for the D-Area powerhouse.

This EIS considers three cooling water alternatives each for K- and C-Reactors and three alternatives for the D-Area powerhouse. The alternatives for K- and C-Reactors are the construction and operation of once-through cooling towers; the construction and operation of recirculating cooling towers; and the continuation of direct discharge - or no action [as required by the Council on Environmental Quality for Implementing the National Environmental Policy Act (40 CFR 1502.14)]. The three alternatives for the D-Area powerhouse are to increase the inlet water flow to the D-Area raw-water basin; to implement direct discharge to the Savannah River; and to continue the present operation - or no action.

This EIS describes the cooling water alternatives (Chapter 2) and the affected Savannah River Plant environment (Chapter 3), and assesses the potential environmental consequences of construction and operation of alternative cooling water systems, including cumulative and unavoidable and irreversible

impacts (Chapter 4). Chapter 5 discusses Federal and State of South Carolina regulatory requirements/permits and studies and monitoring programs that are applicable to the construction and operation of the cooling water systems.

BB-1 | Eight documents published in the last 3 years are relevant to an understanding
BD-5 | of the potential environmental effects of the construction and operation of
alternative cooling water systems:

- Environmental Impact Statement, L-Reactor Operation, Savannah River Plant, Aiken, South Carolina (DOE, 1984a) describes alternative cooling water systems for L-Reactor and the potential environmental effects of these systems on the Savannah River and the onsite swamp system.
- Thermal Mitigation Study - Compliance with the Federal and South Carolina Water Quality Standards, Savannah River Plant, Aiken, South Carolina (DOE, 1984b) discusses and evaluates 22 possible cooling water alternatives for K- and C-Reactors and the D-Area powerhouse.
- The Comprehensive Cooling-Water Study Annual Report and Final Report, Savannah River Plant, Aiken, South Carolina (Du Pont, 1985; 1987) evaluates the environmental effects of the intake and release of cooling water on the structures and functions of aquatic ecosystems at the Savannah River Plant, including water quality, radionuclide and heavy metal transport, wetlands ecology, aquatic ecology, and endangered species.
- Draft Environmental Impact Statement, Alternative Cooling Water Systems, Savannah River Plant, Aiken, South Carolina (DOE, 1986) describes alternative cooling water systems for K- and C-Reactors and the D-Area powerhouse and the potential environmental effects of these systems on the Savannah River and the onsite streams.
- Impingement and Entrainment at the River Water Intakes of the Savannah River Plant (DOE, 1987) summarizes the impact of withdrawing Savannah River water for secondary cooling of SRP nuclear reactors and a large, coal-fired, steam generation facility on the Savannah River fisheries.
- Chlorination/Dechlorination Studies Relating to Proposed Cooling Towers for K- and C-Reactors (Wilde, 1986) provides information on the chlorination and dechlorination of SRP reactor cooling water pumped from the Savannah River.
- Habitat Evaluation Procedure (HEP) Assessment for Thermal Mitigation Alternatives for C- and K-Reactors (Mackey et al., 1987) identifies the value of habitat to be gained or lost with the implementation of once-through or recirculating cooling towers.

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BC-2

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- Mackey, H. E., Jr., C. E. Davis, L. Price, and W. Fay, 1987. Habitat Evaluation Procedure (HEP) Assessment for Thermal Mitigation Alternatives for C- and K-Reactors, DPST-87-578, E. I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, South Carolina. BC-2
- Wilde, E. W., 1986. Chlorination/Dechlorination Studies Relating to Proposed Cooling Towers for K- and C-Reactors, DP-1730, E. I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, South Carolina. BE-1
BC-16

CHAPTER 2

COOLING WATER ALTERNATIVES AND PROPOSED ACTION

The U.S. Department of Energy (DOE) initially identified possible cooling water systems that it could implement for the K- and C-Reactors and the D-Area coal-fired powerhouse, and documented them in the Thermal Mitigation Study (DOE, 1984b). Based on a structured screening process and comments received on its Notice of Intent to prepare this environmental impact statement (EIS), DOE has identified reasonable cooling water alternatives that this EIS considers in detail.

Section 2.1 describes the screening process by which DOE determined the reasonable cooling water alternatives considered in this EIS; Section 2.2 describes these alternatives; Section 2.3 compares the environmental consequences of these alternatives.

2.1 SCREENING PROCESS

DOE used a structured screening process to identify, from among the many possible alternatives for cooling water systems for K- and C-Reactors and the D-Area coal-fired powerhouse, those that would be reasonable from environmental, engineering, scheduling, and cost perspectives. The Thermal Mitigation Study (DOE, 1984b) documents this screening process. DOE performed this screening in a three-step process:

1. Identification of possible alternatives
2. Selection of feasible compliance alternatives using "exclusionary" criteria
3. Selection of reasonable compliance alternatives using "discriminatory" criteria

The first step divided all alternative cooling water systems into two categories: those that could meet the State of South Carolina's Class B water classification standards and those that could not. For those alternatives that could not meet these water classification standards (such as rubble dams, small cooling lakes, and the current once-through systems), DOE did not consider any further assessment because both Federal and State regulations would prohibit the designation of streams to a classification other than Class B for the transport or assimilation of waste.

For those alternatives that could meet Class B water classification standards, DOE identified potential subcategories of generic cooling water systems for K- and C-Reactors and, separately, for the D-Area coal-fired powerhouse. These systems were:

- Cooling towers
 - Once-Through
 - Recirculating

- Cooling lakes and ponds
 - Offstream ponds
 - Cooling lakes
 - Multisource ponds/lakes
- Cooling lake/pond and cooling-tower combinations
 - Cooling lakes/ponds before cooling towers
 - Cooling lakes/ponds after cooling towers

For the D-Area coal-fired powerhouse, the identified alternatives included:

- Cooling towers
 - Once-Through
 - Recirculating
- Direct discharge to the Savannah River
- Increased flow with mixing

DOE then developed minimum requirements for K- and C-Reactors for use in identifying possible alternatives for each of the generic categories. These requirements included sufficient surface area in cooling lakes or ponds for heat dissipation, and sufficient cooling capacity in once-through and recirculating cooling towers to attain a 32.2°C discharge during extreme meteorological conditions. Using these minimum requirements, DOE identified 22 possible cooling water alternatives for K- and C-Reactors and 4 alternatives for the D-Area powerhouse.

DOE applied "exclusionary criteria" to the possible cooling water alternatives to identify the feasible compliance alternatives. For K- and C-Reactors, the exclusionary criteria consisted of:

- The expected ability to perform successful Section 316(a) demonstrations if the Class B temperature limits were to be exceeded in the receiving stream after mixing
- A minimum of 400 acres of cooling-lake surface at or below 32.2°C to support a balanced biological community
- Sufficient cooling capacity to require, for screening purposes, no more than a 10 percent annual average production loss.

Application of these criteria led to the identification of 17 feasible compliance alternatives for K- and C-Reactors. DOE considered each of the four possible cooling water alternatives for the D-Area powerhouse to be feasible.

In the third step, DOE screened the 17 feasible compliance alternatives for K- and C-Reactors and the 4 alternatives for the D-Area powerhouse on the basis of "discriminatory" criteria to determine the reasonable compliance alternatives. These criteria included environmental impacts, implementation schedules, capital and operating costs, and relative operating complexity (i.e., multiple reactor cooling systems versus recirculation systems versus

once-through systems). Based on these discriminatory criteria, DOE identified the following reasonable compliance alternatives:

K-Reactor

- 1400-acre once-through cooling lake between Pen Branch and Four Mile Creek above the railroad track
- Recirculating cooling tower
- Once-Through cooling tower
- Once-Through cooling tower to a 600-acre once-through cooling lake on Indian Grave Branch with an embankment about 300 meters above the confluence with Pen Branch
- 800-acre cooling lake with a 400-acre hot arm to a once-through cooling tower with an embankment located about 610 meters above Road A on Pen Branch

C-Reactor

- 1400-acre once-through cooling lake between Pen Branch and Four Mile Creek below the railroad track
- Recirculating cooling tower
- Once-Through cooling tower
- Once-Through cooling tower to a 500-acre once-through cooling lake on a tributary of Four Mile Creek with an embankment about 300 meters above the confluence with Four Mile Creek
- 800-acre cooling lake with a 400-acre hot arm to a once-through cooling tower with an embankment on Four Mile Creek about 1280 meters above Road A

D-Area Powerhouse

- Direct discharge to the Savannah River (bypassing Beaver Dam Creek)
- Increased flow with mixing

As part of the scoping process, DOE invited interested parties to comment on the alternatives it would consider in this environmental impact statement (50 FR 30728). Based on the screening process documented in the Thermal Mitigation Study (DOE, 1984b) and its preliminary determination of alternatives to be considered in this environmental impact statement, DOE decided to consider the alternatives of once-through and recirculating cooling towers for K- and C-Reactors, and increased flow with mixing and direct discharge to the Savannah River for the D-Area coal-fired powerhouse. In addition, DOE is required to consider the "no action" alternative in accordance with the Council on Environmental Quality's regulations for implementing the procedural provisions of the National Environmental Policy Act (NEPA).

Appendix A provides a more detailed description of the screening process and criteria that DOE used to identify the reasonable alternatives for evaluation in this environmental impact statement.

2.2 PROPOSED ACTION

The proposed action is to construct and operate cooling water systems for the K- and C-Reactors and the D-Area powerhouse to attain compliance with the State of South Carolina's Class B water classification standards. Based on the screening process described in Section 2.1, the alternatives considered in this EIS are the construction and operation of once-through or recirculating cooling towers for K- and C-Reactors, increased flow with mixing or direct discharge to the Savannah River for the D-Area powerhouse, and no action. DOE's preferred alternatives are to construct and operate once-through cooling towers for K- and C-Reactors and to implement increased flow with mixing for the D-Area powerhouse.

The following sections describe these alternatives. The descriptions are based on preliminary and conceptual designs; specific engineering parameters and costs are subject to change during future design phases.

2.2.1 K-REACTOR COOLING WATER ALTERNATIVES

The cooling water alternatives for K-Reactor are the construction and operation of a once-through cooling tower, the construction and operation of recirculating cooling towers, and no action.

2.2.1.1 Once-Through Cooling Tower (Preferred Alternative)

TC	The once-through cooling tower described in the <u>Thermal Mitigation Study</u> (DOE, 1984b) and the draft EIS (DOE, 1986) was a mechanical-draft tower that would receive the cooling water from K-Reactor from a new pump pit. Cooled water from the tower basin would then flow by gravity to a 100-acre offstream holding pond which would be used to dissipate chlorine (cooling-tower biocide), before the water was discharged to Indian Grave Branch and Pen Branch. The thermal performance of the once-through cooling system was not designed to utilize the holding pond for additional cooling.
AD-1	Since the completion of the <u>Thermal Mitigation Study</u> and the Draft EIS (DOE, 1986), further design evaluations and studies have been performed to determine optimal performance parameters and to achieve lower costs. These evaluations and studies have indicated that there are several areas in which optimization of performance and cost savings can be realized in the construction and operation of once-through towers without introducing major changes in the nature or magnitude of the environmental impacts. These areas include the consideration of gravity-feed versus pumped-feed towers, natural-draft versus mechanical-draft towers, and a chemical injection system for either dissipation or neutralization of chlorine biocide versus holding ponds (and their sizing). Similarly, these evaluations and studies have also led to the development of thermal performance criteria that, when incorporated in the final design of a
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once-through cooling-tower system, would reduce the potential for cold shock (i.e., reduce the difference between ambient stream temperatures and stream temperatures when the cooling water is being discharged) to fish.

The following sections describe the once-through cooling-tower for K-Reactor incorporating current design considerations, and the major differences associated with a natural-draft versus a mechanical-draft tower.

Description

For a once-through natural-draft system with gravity feed, the cooling water discharged from K-Reactor would flow by gravity from a new underground reinforced-concrete diversion box constructed around the existing effluent pipe, through a new 1.8-meter diameter pipe approximately 50 meters long to a new riprap-lined effluent canal. This canal would begin just outside of the Reactor Area fence and would extend southwesterly under Road B approximately 750 meters to a collection box to be constructed approximately 300 meters south of Road B. The box would channel the cooling water into another 1.8-meter-diameter pipe, which would deliver it to a natural-draft cooling tower located between Road B and Indian Grave Branch, discharges from which would enter the Branch. Figures 2-1 and 2-2, which are based on preliminary design information, show a flow diagram and a site layout, respectively, of this once-through system.

TC

Based on preliminary design information, the natural-draft, once-through, reinforced-concrete cooling tower would be approximately 100 meters in diameter and about 150 meters high. The tower would utilize Chlorinated Polyvinyl Chloride (CPVC) and Polyvinyl Chloride (PVC) fill to withstand the high cooling water temperatures. The tower would be situated over a reinforced-concrete basin, which would receive the cooled water flowing through the tower. An underground steel pipe would carry the flow by gravity to a new riprap-paved canal 50 meters long and 30 meters wide that would convey cooled effluent into Indian Grave Branch at a point 800 meters downstream from the present discharge point of the K-Reactor effluent canal.

A small water-treatment building would be located near the cooling tower. It would be used to store a chemical biocide (probably sodium hypochlorite) that would be injected into the cooling water stream at the tower inlet to prevent biofouling in the tower system.

BB-1
BB-2

This building would contain a system for injecting a dechlorination agent (probably sodium sulfite) into the cooling tower cold water basin. The dechlorinating agent would be injected in sufficient quantities to meet established chlorine effluent limits. Chemical storage tanks and distribution piping would be provided, as would metering pumps and controls, which would be located in the small water-treatment building near the cooling tower.

BB-1

A new control room located near the cooling tower would contain the necessary switchgear and instrumentation for the operation of all chemical-treatment equipment.

TC

The cooling-tower area would be enclosed by a patrol road and fence with personnel and vehicular gates. Access roads would be provided, and parking, loading, and equipment storage areas would be paved at the cooling tower and

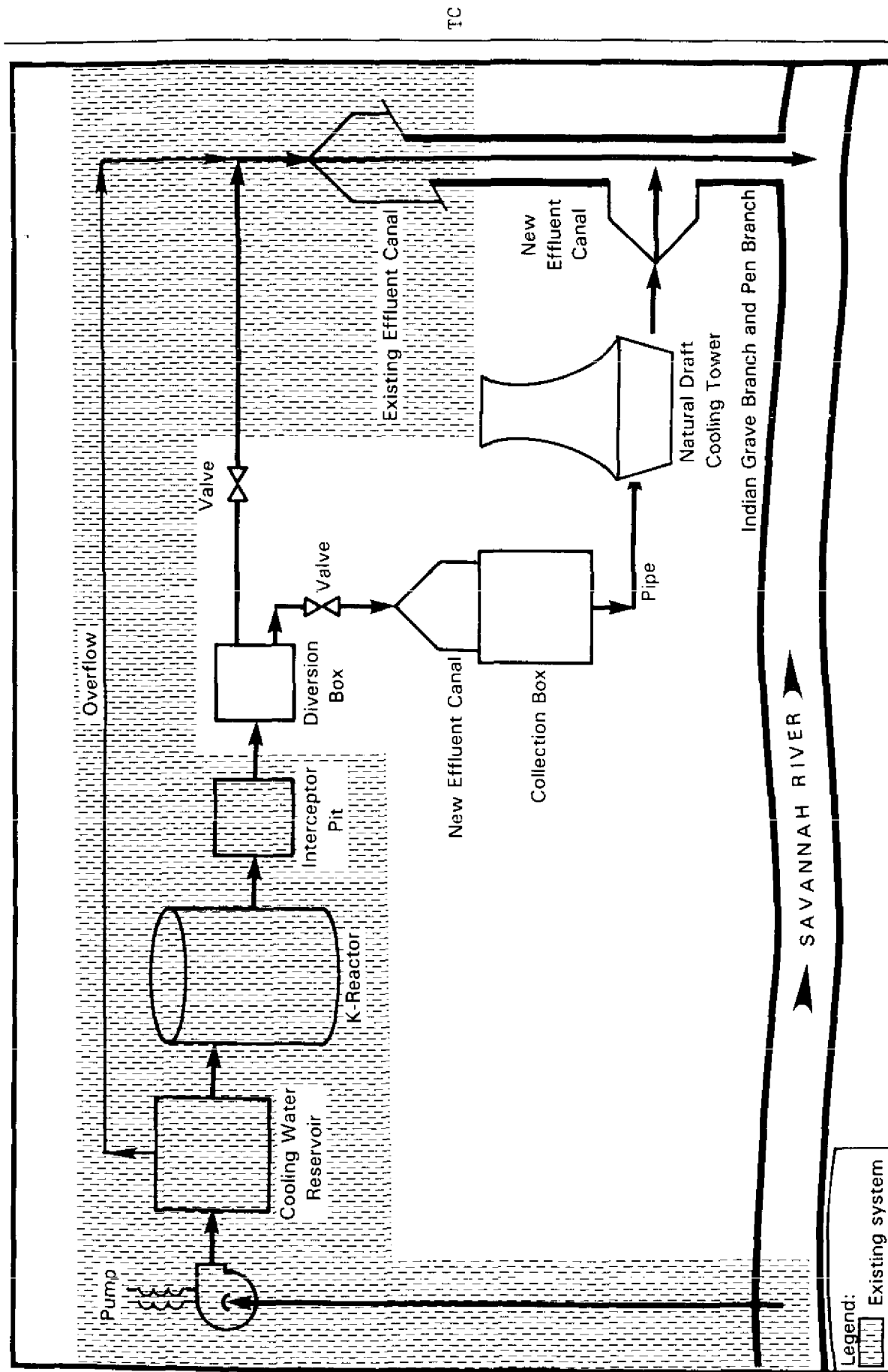


Figure 2-1. K-Reactor Once-Through Cooling Tower System Flow Diagram

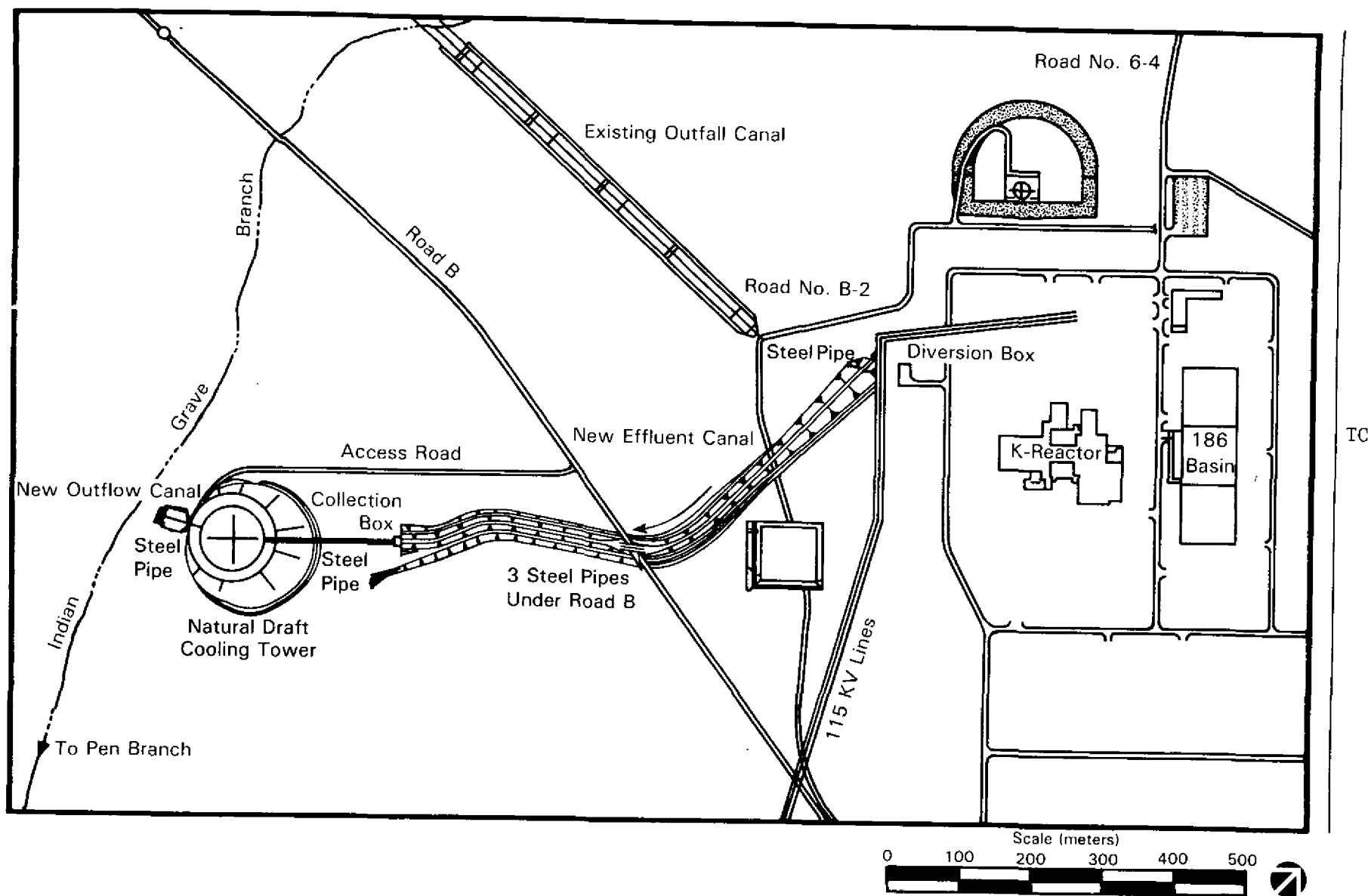


Figure 2-2. K-Reactor Once-Through Cooling Tower System

accessory buildings. Areas around the cooling tower would be regraded and seeded, or, if necessary, covered with stone or paving as appropriate to restore natural surface drainage. An adequate stormwater-drainage system would be constructed inside the fenced area; it would include erosion protection and would discharge into natural drainage ways.

TC

Electrical loads for the gravity-feed, natural-draft cooling tower system would be small, consisting primarily of lighting and control equipment. The existing K-Area substations should be adequate, but two new electric lines would be run from K-Area to the cooling tower area along the proposed canal.

Outside lighting and power distribution at the new cooling-tower facilities would be provided. Communications facilities would be extended from the existing K-Area system. Monitoring instrumentation for this cooling system would be installed in the K-Reactor Central Control Room. It would contain monitoring and control instruments that would be connected to instrumentation at the cooling-tower facilities. These instruments would measure water temperature at the tower discharge and water flow to the stream. New alarms in the Central Control Room would indicate a high cooling-tower discharge temperature.

Most of the cooling water system construction would be completed with minimal impact on reactor operation. Careful scheduling would ensure that the work necessary to connect the system with the existing facilities is accomplished during scheduled reactor shutdowns.

Safety practices during construction would be in accordance with applicable safety standards. Occupational exposure to low-level radiation and to chemical contact or inhalation will be minimized by monitoring procedures and by protective equipment and clothing.

TC

Preliminary design evaluations and studies have indicated that optimization of performance and cost savings would be realized by the construction and operation of a natural-draft, once-through cooling tower rather than a mechanical-draft tower as described in the Thermal Mitigation Study (DOE, 1984b) and the draft EIS (DOE, 1986). The description of a mechanical-draft tower would not differ appreciably from that presented above for the natural-draft tower. The major differences would be the size of the tower (e.g., approximately 150 meters high for the natural-draft tower versus 20 meters for the mechanical-draft tower) and the extent of the electrical system upgrade (e.g., the natural-draft tower could require less system upgrade due to the elimination of the fans and motors associated with the mechanical-draft tower).

Thermal Performance

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BC-4
BC-14

The once-through cooling tower would be designed to enable the discharge to meet the State of South Carolina's Class B water classification standards (i.e., a maximum instream temperature of 32.2°C). This would be accomplished through the design conditions of a 4.4°C approach to a wet bulb temperature of 27.8°C. In the rare instances where the design wet bulb is exceeded, the reactor will be operated at reduced power so that the standards are always met.

The K-Reactor tower discharge to Pen Branch includes the 11.3 cubic meters per second of secondary cooling water flow, less approximately 0.8 cubic meter per second of water evaporated in the tower. The Pen Branch flow (at Road B), other than the K-Reactor effluent, is approximately 0.03 cubic meter per second.	TC
Table 2-1 lists monthly average water temperatures along the cooling water flow path (based on Bush Field meteorology data from 1953 through 1982), along with the ambient stream temperatures. Additionally, Table 2-1 lists downstream temperatures under extreme summer conditions (July 1980).	TC TE
The cooling tower will be designed and operated in such a manner as to meet the maximum weekly average temperature (MWAT) criteria (EPA, 1977) to minimize thermal shock of fish that could occur with a reactor scram (Muhlbaier, 1986). During average winter and spring conditions, the discharge from the once-through cooling tower would raise the ambient stream temperature in Pen Branch above the 2.8°C maximum temperature rise specified in the State of South Carolina's Class B water classification standards. Accordingly, a Section 316(a) study would be performed to demonstrate whether a balanced biological community would be maintained.	TE
<u>Resource Utilization</u>	
The existing withdrawal of about 11.3 cubic meters per second of water from the Savannah River to K-Reactor would be unchanged for the once-through cooling-tower alternative. Discharges from K-Reactor to the river would be reduced by about 0.8 cubic meter per second because of evaporation, and the total suspended solids concentration would be reduced by settlement in the cooling-tower cold water basin. Chemical biocide added to the cooling water to protect the tower would be neutralized. All discharges would meet State of South Carolina Class B water classification standards.	BB-1 BB-2
Construction of a once-through natural-draft cooling tower system would be completed in approximately 36 months after a 9-month lead design period. The estimated peak contractor manpower requirement, based on preliminary design information, is about 200 persons for K-Reactor, assuming a combined workforce with C-Reactor. The maintenance and operating workforce would be increased by approximately four mechanics. Approximately 25 acres of uplands would be disturbed by all construction activities.	TC TC
Since the once-through cooling tower system is gravity flow with a natural draft tower, the additional electricity requirements would be only for lighting and chemical feed equipment.	TC
The present peak electrical load in K-Area is about 30.3 megawatts. An insignificant quantity of additional power would be required for lighting and other electrical equipment.	TC
The estimated present-worth cost for the once-through natural-draft cooling tower at K-Reactor with gravity feed is approximately \$43 million, including production losses (\$41.4 million without production losses). Estimated annual operating costs are \$6.4 million. In addition to these costs, the estimated	AD-1 BC-6

Table 2-1. Monthly Predicted Mean and Maximum (in Parentheses)
Temperatures (°C) Along Cooling Water Flow
Path of K-Reactor Once-Through Cooling Tower

Location	Temperature for											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Discharge to creek	19(28)	20(28)	23(28)	24(30)	26(30)	28(31)	29(32)	29(32)	28(31)	24(31)	23(29)	21(28)
Pen Branch at												
Road A	18(27)	19(27)	22(27)	24(29)	26(30)	28(31)	29(32)	29(32)	28(31)	24(30)	22(28)	20(27)
Railroad bridge	18(26)	18(26)	21(26)	23(29)	26(30)	28(31)	29(31)	29(31)	28(30)	24(29)	21(27)	19(26)
Swamp delta	16(24)	17(24)	20(25)	23(27)	25(29)	28(30)	29(31)	28(31)	27(30)	23(28)	20(26)	18(24)
Upstream from Steel												
Creek	10(17)	12(17)	16(19)	18(21)	21(24)	24(26)	26(27)	25(27)	23(24)	18(21)	15(18)	11(16)
Mouth ^a	10(15)	12(16)	16(19)	18(20)	21(24)	24(26)	25(27)	25(26)	22(24)	17(21)	15(17)	11(15)
Ambient creek ^b	8(18)	10(18)	15(22)	18(23)	21(24)	23(27)	23(27)	23(26)	21(26)	19(23)	13(21)	12(17)

a. Includes Steel Creek flow.

b. U.S. Geological Survey data for water year 1985 for station 021973471; Pen Branch at Road B (USGS, 1986).

BB-3
BC-4
BC-14

cost to conduct a Section 316(a) demonstration study is estimated \$1.25 million. Preliminary design criteria suggest a 0.2-percent annual average loss of reactor power attributable to the operation of a once-through cooling-tower system in comparison to the No-Action alternative.

AD-1
BC-6

2.2.1.2 Recirculating Cooling Towers

If a closed-cycle, recirculating cooling tower system were selected to be constructed, the cooling water discharges from K-Reactor would be conveyed initially in the same manner as in the once-through system (i.e., the same diversion box, pipe, canal, collection box, and pipe). However, the natural-draft cooling tower would be somewhat smaller than in the once-through design and the discharge from this tower would be pumped to a mechanical-draft tower near the existing K-Reactor cooling water reservoir (186-K basin). Figures 2-3 and 2-4, which are based on preliminary design information, show a flow diagram and a site layout, respectively, of this recirculating system.

The natural-draft cooling tower, when installed with the mechanical-draft tower in series, would be approximately 85 meters in diameter and 120 meters high. Six 1750 horsepower (1300 kilowatt) pumps would be provided to transfer the cooling water from the cold water basin under the first tower through a new steel pipe to the second tower. This 1.8-meter diameter, underground steel pipe would run approximately 2 kilometers from the natural-draft tower northeasterly under Road B and around the south and east sides of K-Area to the inlet of the mechanical-draft cooling tower. This second tower would be constructed on top of about 5 meters of earth fill, so its discharge could flow by gravity back to the Building 186-K basin for reuse.

AD-1
BC-13

The first tower would utilize chlorinated polyvinyl chloride (CPVC) and polyvinyl chloride (PVC) fill to withstand the high cooling water temperatures. The second tower could use standard polyvinyl chloride fill, because the water reaching this tower would have been partially cooled at the first tower. The second tower would be approximately 70 meters in diameter by 20 meters high, and would have 12 fans, each with a 190-kilowatt motor.

A small water-treatment building would be located near each cooling tower. The buildings would be used to store a chemical biocide (probably sodium hypochlorite) that would be injected into the cooling water stream to prevent biofouling in the tower system. This would allow for injection of a non-chromated, organic based, chemical corrosion inhibitor. This chemical has been approved by SCDHEC for use in cooling tower systems and is presently being used at SRP.

BB-1
BB-2
BC-17

Since the recirculating system would be designed to reduce production loss as well as to meet environmental regulations, no piping has been provided to completely bypass any cooling tower. Internal bypass valves would be included in each cooling tower to divert water directly to the cold water basin. These bypass valves, as well as sectionalizing valves which can isolate parts of the tower fill, would be used for cold weather start-ups and could be used during equipment repairs, if necessary.

AD-1
BC-13

Whenever water is recirculating, approximately 0.5 cubic meter per second of the second tower discharge would flow by gravity through a weir to the existing overflow pipeline from Building 186-K. This pipeline would flow by

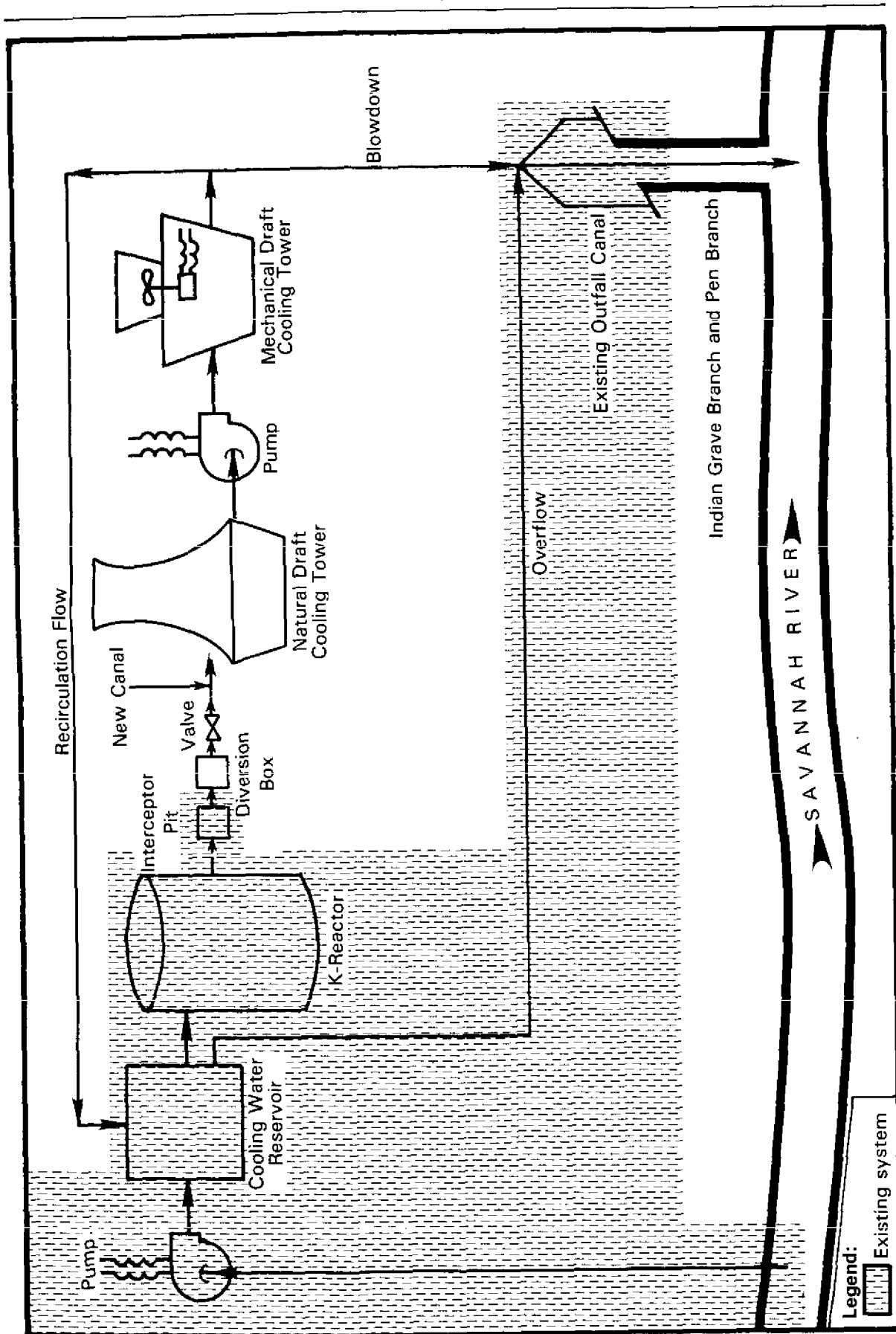


Figure 2-3. K-Reactor Recirculating Cooling Tower System Flow Diagram

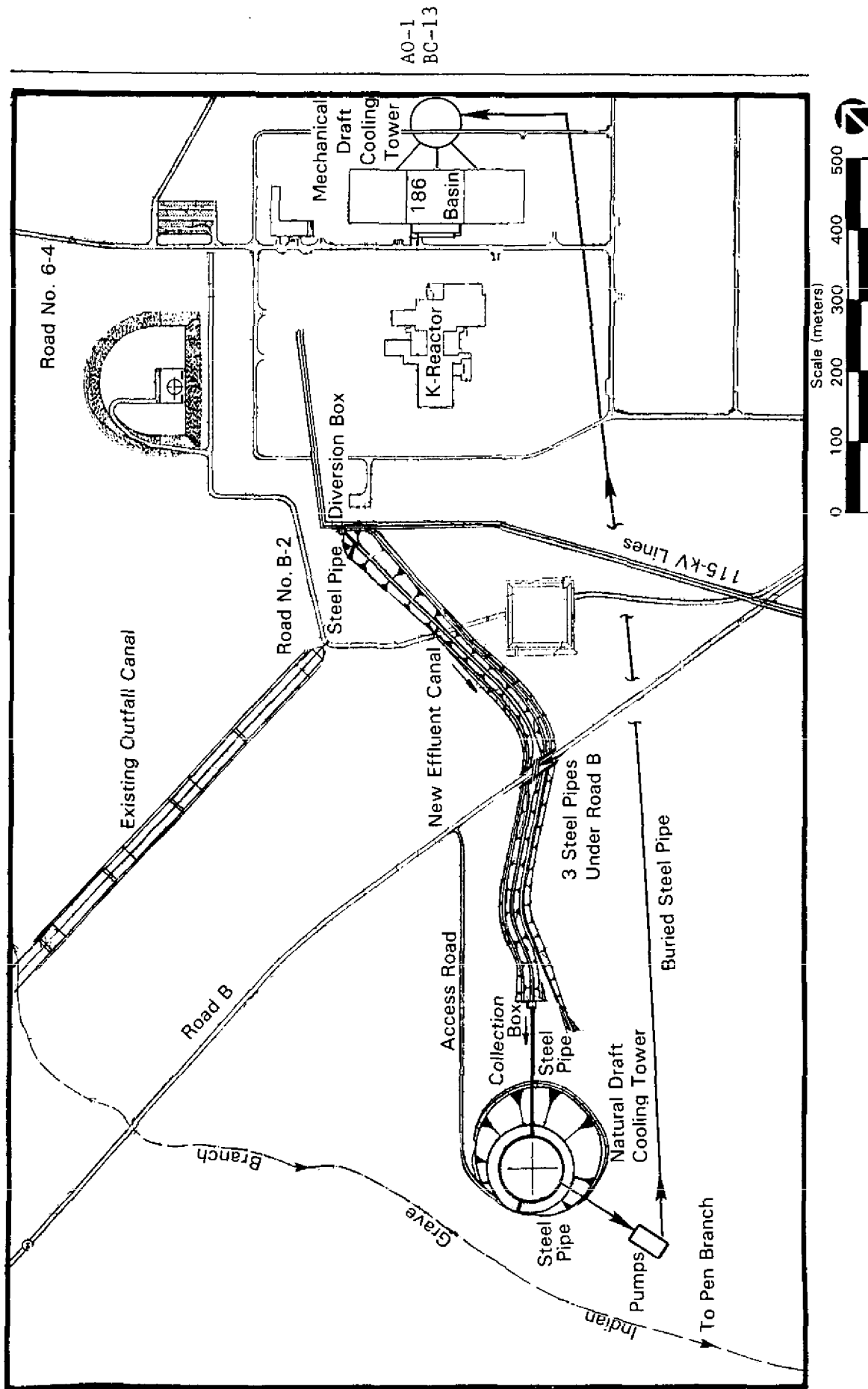


Figure 2-4. K-Reactor Recirculating Cooling Tower System

AO-1
BC-13 gravity back into the existing outfall canal. The flow would then follow the present path of cooling water to the Savannah River. This blowdown flow is necessary to limit the increase in concentrations of solids and chemicals in the cooling water due to evaporation. The blowdown stream would be treated with a dechlorination chemical (probably sodium sulfite) before reaching the existing outfall canal and Indian Grave Branch.

The natural-draft cooling-tower area would be inside a patrol road and fence as described for the once-through system. Access to this area would be from existing Road B. The existing fence and patrol road along the east side of the K-Reactor area would be relocated to encompass the new mechanical-draft cooling tower and accessories.

A new electrical control room would be located within the K-Reactor production area near the second cooling tower. This room would contain the necessary switchgear and instrumentation for the operation of the cooling tower fans and the chemical-treatment equipment. Another new control room would be constructed near the natural-draft tower for operation of the pumps.

The recirculating system would require an upgrade of two sections of 115-kilovolt overhead line totaling 10.5 kilometers. The upgrade would be the same whether a recirculating system is installed in K-Area or in C-Area or in both areas. Both primary substations in the reactor area would be expanded to handle the increased electrical load.

AO-1
BC-13 Dual 13.8-kilovolt electrical supplies would be provided to each location having recirculating pumps or cooling tower fans.

The recirculation system pumps located at the natural draft cooling tower would be supplied from two independent electrical power supplies. Loss of one power supply could cause temporary loss of one half of the pumps depending on electrical power system design. Recirculation flow could be reduced by up to 50 percent during this period; amount of reduction would be dependent on excess head capacity of the pumps. For conservatism, it is assumed that up to 5.1 cubic meters per second could be discharged to the stream if pumps were not provided with automatic transfer on loss of one electrical power supply.

TC The present design concept for a recirculating system includes pump start/stop buttons and pump running lights. No interlocks would be provided, or are considered necessary, to scram the reactor.

The K-Reactor central control room would be provided with push buttons and motor running lights for six pumps and 12 fans, discharge effluent (blowdown) flow and temperature indicators, and push buttons and position indicators for two diversion box isolation gates.

Thermal Performance

BC-4
BC-14
BC-15 The recirculating cooling tower system would be designed for low tower discharge temperatures leading to compliance with the State of South Carolina's Class B water classification standards (i.e., a maximum instream temperature of 32.2°C). The preliminary design parameters of a 2.8°C approach to a 26.7°C wet bulb will assure compliance with this standard, even at the maximum hourly wet bulb measured at Bush Field (1953 through 1982), 28°C.

For the preliminary design parameters cited above, the blowdown flow to Pen Branch would be about 0.5 cubic meter per second at 2.5 cycles of concentration; the corresponding withdrawal from the Savannah River would be about 1.6 cubic meters per second to make up the blowdown and evaporation losses from the system, as well as auxiliary system flows and 186-K basin overflow.

Table 2-2 lists monthly average water temperatures for the discharge along the cooling water flow path (based on meteorological data at Bush Field from 1953 through 1982), along with the ambient stream temperatures. In addition, Table 2-2 lists downstream temperatures under extreme summer conditions (July 1980). Cooling water discharges from the recirculating cooling-tower system would not always comply with the State of South Carolina's Class B water classification standard that requires that "...free-flowing waters shall not be increased more than 5°F (2.8°C) above natural temperature conditions...." Accordingly, a Section 316(a) study would be performed to demonstrate whether a balanced biological community would be maintained.

BC-4
BC-14
BC-15

Resource Utilization

K-Reactor presently receives approximately 11.3 cubic meters of cooling water per second from the Savannah River. This continuous flow passes through the reactor heat exchangers and discharges down Indian Grave Branch and Pen Branch back to the Savannah River. If the recirculating-cooling-towers alternative were implemented, the discharge from K-Reactor would be reduced to about 1 cubic meter per second. The maximum amount of water removed from the river would also be reduced to about 1.6 cubic meters per second.

TC

TC

This alternative would be constructed in approximately 42 months after a 9-month design period. The estimated peak manpower requirement for K-Reactor is 300 persons, assuming a combined workforce with C-Reactor. The maintenance and operating workforce would be increased by approximately six mechanics. Approximately 50 acres of uplands would be disturbed by all construction activities.

TC

TC

The estimated present peak electrical load for K-Area is about 30.3 megawatts. The electrical load would be decreased approximately 6.4 megawatts because of the 85 percent reduction in electrical load to pump water from the Savannah River to the 186-K basin. The total yearly energy reduction caused by this project would be the equivalent of the electricity produced by the combustion of approximately 12,800 barrels of crude oil.

TC

The estimated present-worth cost of this alternative would be approximately \$90 million including production losses (\$58 million without production losses). Estimated annual operating costs are \$4.4 million. In addition to these costs, the estimated cost to perform a Section 316(a) demonstration study is \$1.25 million. Preliminary design criteria suggest a 3.7-percent annual average loss of reactor power attributable to the operation of a recirculating cooling-tower system in comparison to the no-action alternative.

AD-1
BC-6

2.2.1.3 No Action - Existing System

The existing once-through cooling water system for K-Reactor withdraws approximately 11.3 cubic meters of water per second from the Savannah River at

Table 2-2. Monthly Predicted Mean and Maximum (in Parentheses)
Temperatures ($^{\circ}\text{C}$) Along Cooling Water Flow
Path--K-Reactor Recirculating Cooling Towers

Location	Temperature for											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Discharge to creek	14(25)	15(25)	18(26)	20(28)	23(28)	26(29)	27(30)	26(30)	25(29)	20(28)	18(27)	15(26)
Pen Branch at												
Road A	11(19)	12(18)	16(20)	19(24)	23(27)	26(28)	27(29)	27(29)	24(27)	19(25)	15(21)	12(19)
Railroad bridge	9(17)	11(17)	15(19)	19(23)	23(26)	26(28)	27(29)	27(29)	24(27)	18(23)	15(19)	11(17)
Swamp delta	8(15)	11(16)	15(18)	19(22)	23(26)	26(28)	28(29)	27(29)	24(26)	17(21)	14(17)	9(15)
Upstream from Steel												
Creek	7(14)	10(14)	14(16)	15(17)	17(20)	21(23)	23(24)	22(23)	18(19)	13(17)	12(15)	8(12)
Mouth ^a	10(14)	11(15)	15(19)	18(20)	21(24)	25(26)	25(27)	23(24)	20(23)	13(19)	15(17)	11(14)
Ambient creek ^b	8(18)	10(18)	15(22)	18(23)	21(24)	23(27)	23(27)	23(26)	21(26)	19(23)	13(21)	12(17)

a. Includes Steel Creek flow.

b. U.S. Geological Survey data for water year 1985 for station 021973471; Pen Branch at Road B (USGS, 1986).

BB-3
BC-14

the 1G and 3G pumphouses. From these pumphouses the water passes through an interconnected network of underground pipe to the Building 186-K basin which has a capacity of approximately 95,000 cubic meters.

The cooling water is drawn by gravity through the reactor heat exchangers to an interceptor pit and then through an underground steel pipe. The water flows to a reinforced-concrete headwall at the existing K-Reactor cooling water outfall canal. This canal, lined with concrete and stone riprap, dissipates the energy of the discharge as it flows to Indian Grave Branch. The discharge then flows along Indian Grave Branch and Pen Branch and into the Savannah River about 8 kilometers downstream from the D-Area powerhouse and the river-water pumping stations.

K-Reactor discharges approximately 11.3 cubic meters of reactor cooling water per second at an average temperature of 70°C to 77°C. This flow includes 10.5 to 10.9 cubic meters per second from the reactor heat exchangers and 0.3 to 0.6 cubic meter per second of service water and other flows. It does not include any overflow from the 186-K basin, which is normally 0.2 cubic meter per second but can be as high as 0.95 cubic meter per second. This overflow is always at ambient water temperature; therefore, it adds no heat load. Estimated annual operating costs for the no-action alternative are \$6.2 million.

Thermal Performance

Approximately 96 percent of the 11.3 cubic meters (10.5 to 10.9 cubic meters per second) pumped from the Savannah River to K-Area is used as secondary cooling water, with the remainder (0.3 to 0.6 cubic meter) used for auxiliary systems. The temperature of the secondary cooling-system water discharge normally ranges between 47°C (average summer) and 61°C (average winter) above ambient. Virtually the entire flow withdrawn from the Savannah River is discharged to Pen Branch, with the auxiliary systems water mixing with the heated secondary cooling water.

TC

The temperature of the effluent water varies with the temperature of the river water, although the seasonal fluctuations of the latter are moderated by an inverse relationship between intake water temperature and temperature increase. Table 2-3 indicates monthly average and extreme temperatures along the cooling water flow path, along with ambient stream temperatures. The downstream heat-loss characteristics are based on meteorological data from Bush Field between 1953 and 1982; the extreme summer conditions are for July 1980.

Table 2-3 illustrates that the State of South Carolina's Class B water classification standard of a maximum instream temperature of 32.2°C is exceeded at all times along points in the stream during the operation of K-Reactor. The heat loss along the stream implies an evaporation rate of approximately 0.5 cubic meter per second between the discharge and the delta - less than 5 percent of the discharge flow.

Table 2-3. Monthly Predicted Mean and Maximum (in Parentheses)
Temperatures (°C) Along K-Reactor Cooling Water Flow
Path: No Action (Existing System)

Location	Temperature for											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Discharge to outfall	69(70)	69(71)	70(72)	71(73)	72(73)	73(74)	74(75)	74(75)	73(75)	72(74)	71(73)	70(72)
Pen Branch at												
Road A	61(63)	60(62)	61(63)	63(65)	66(67)	67(68)	68(69)	68(69)	68(69)	67(68)	64(66)	62(64)
Railroad bridge	52(54)	51(53)	52(54)	55(56)	57(59)	59(60)	59(60)	60(60)	59(60)	58(59)	54(56)	53(55)
Swamp delta	42(44)	42(44)	43(44)	46(48)	48(50)	50(51)	51(51)	51(51)	50(51)	48(49)	45(46)	43(45)
Upstream from Steel												
Creek	16(21)	17(21)	20(22)	24(26)	27(29)	29(30)	30(31)	30(31)	28(29)	24(26)	20(22)	17(20)
Mouth ^a	13(17)	15(18)	18(21)	21(23)	24(27)	27(28)	28(29)	28(29)	26(27)	22(24)	17(19)	14(17)
Ambient creek ^b	8(18)	10(18)	15(22)	18(23)	21(24)	23(27)	23(27)	23(26)	21(26)	19(23)	13(21)	12(17)

a. Includes Steel Creek flow.

b. U.S. Geological Survey data for water year 1985 for station 021973471; Pen Branch at Road B (USGS, 1986).

BB-3
BC-14

2.2.2 C-REACTOR COOLING WATER ALTERNATIVES

The cooling water alternatives for C-Reactor are the construction and operation of a once-through cooling tower, the construction and operation of recirculating cooling towers, and no action.

2.2.2.1 Once-Through Cooling Tower (Preferred Alternative)

The once-through cooling tower described in the Thermal Mitigation Study (DOE, 1984b) and the draft EIS (DOE, 1986) is a mechanical-draft tower that would receive the cooling water from C-Reactor from a new pump pit. Cooled water from the tower basin would then flow by gravity to a 100-acre offstream holding pond, which would be used to dissipate chlorine (cooling tower biocide) before the water was discharged to Four Mile Creek. The thermal performance of the once-through cooling-tower system was not designed to utilize the holding pond for any additional cooling.

TC

Since the completion of the Thermal Mitigation Study and the Draft EIS (DOE, 1986), further design evaluations and studies have been performed to determine optimal performance parameters and to achieve lower costs. These evaluations and studies have indicated that there are several areas in which optimization of performance and cost savings can be realized in the construction and operation of once-through towers without introducing major changes in the nature or magnitude of the environmental impacts. These areas include the consideration of gravity-feed versus pumped-feed towers, natural-draft versus mechanical-draft towers, and a chemical injection system for either dissipation or neutralization of chlorine biocide versus holding ponds (and their sizing). Similarly, these evaluations and studies have also led to the development of thermal performance criteria that, when incorporated in the final design of a once-through cooling-tower system, would reduce the potential for cold shock (i.e., reduce the difference between ambient stream temperatures and stream temperatures when the cooling water is being discharged) to fish.

AD-1
BB-1
BB-2
BB-3
BB-4
BC-6
BC-14

The following sections describe the once-through cooling-tower for C-Reactor incorporating current design considerations, and then the major differences associated with a natural-draft versus a mechanical-draft tower.

TC

Description

For a once-through natural-draft system with gravity feed, the cooling water discharged from C-Reactor would flow by gravity from a new underground reinforced-concrete diversion box constructed around the existing effluent pipe, through a new 1.8-meter diameter pipe approximately 100 meters to a new riprap-lined effluent canal. This canal would begin just outside of the Reactor Area fence and would extend southwesterly approximately 1160 meters to a collection box to be constructed approximately 120 meters north of Road 3. The box would channel the cooling water into another 1.8-meter-diameter pipe, which would deliver it under Road 3 to a natural-draft cooling tower located between Road 3 and Castor Creek, a small tributary of Four Mile Creek, discharges from which would enter Castor Creek. Figures 2-5 and 2-6, which are based on preliminary design information, show a flow diagram and a site layout, respectively, of this once-through system.

TC

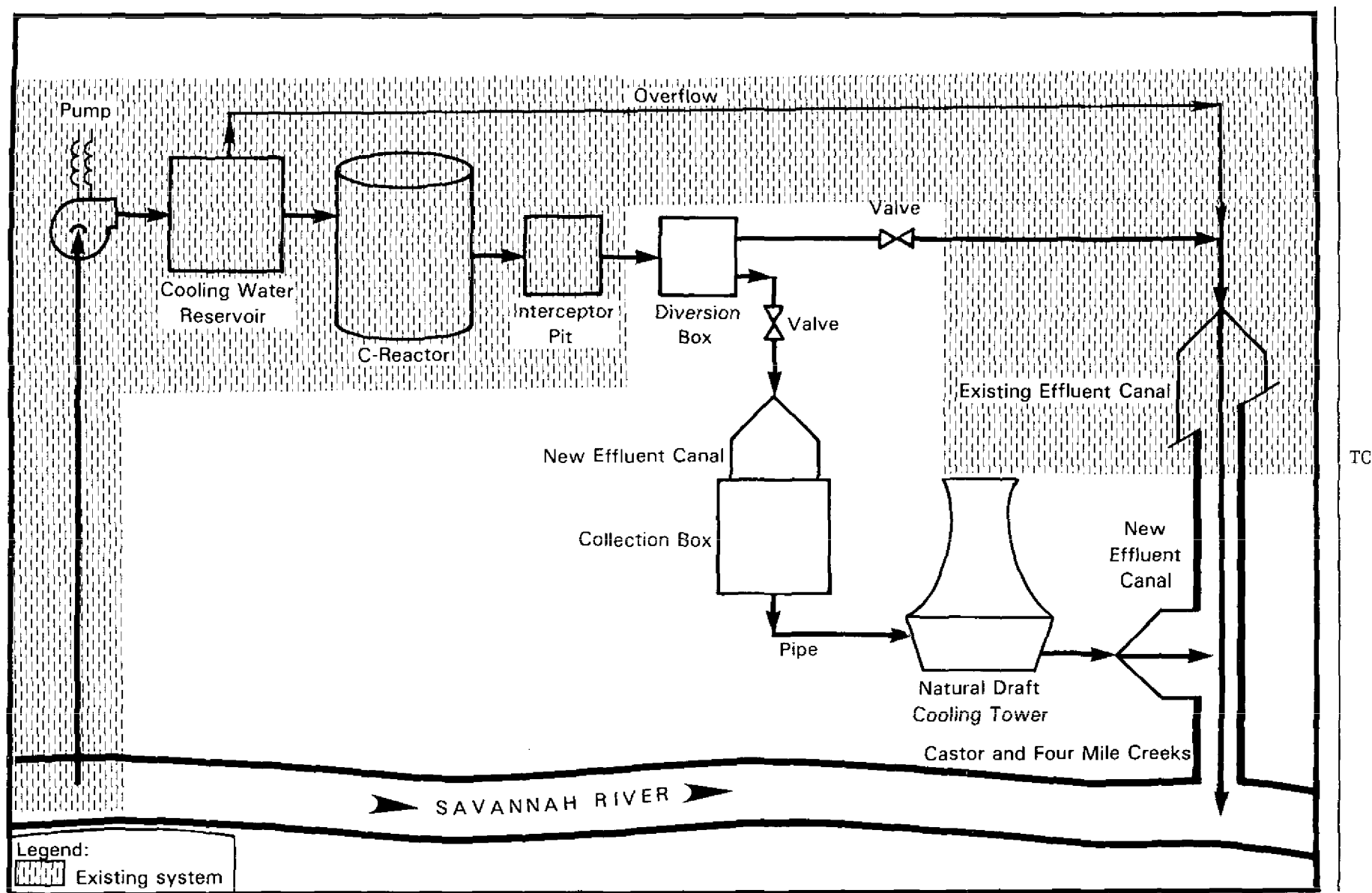


Figure 2-5. C-Reactor Once-Through Cooling Tower System Flow Diagram

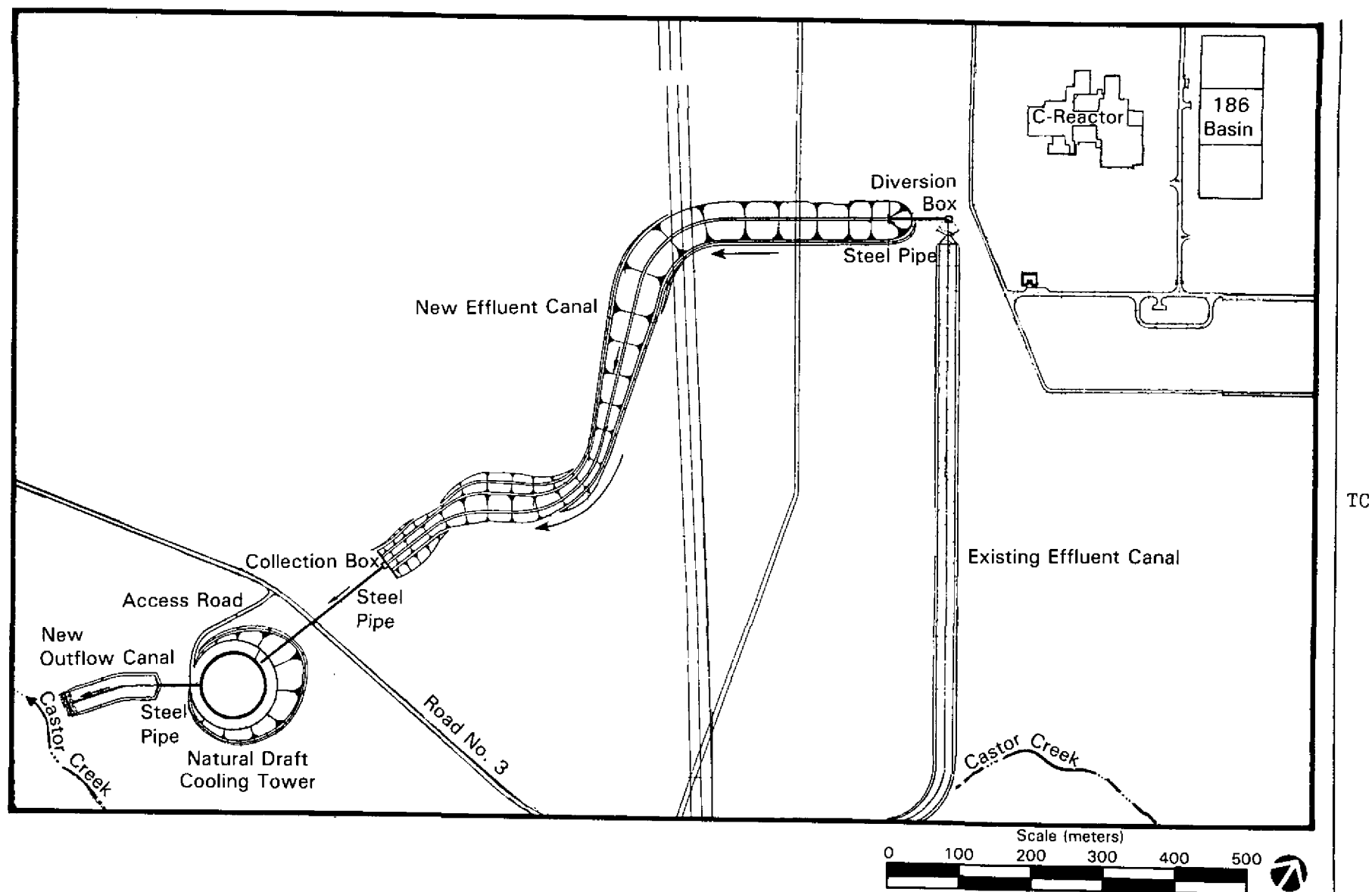


Figure 2-6. C-Reactor Once-Through Cooling Tower System

TC Based on preliminary design information, the natural-draft, once-through, reinforced-concrete cooling tower would be approximately 100 meters in diameter and about 150 meters high. The tower would utilize Chlorinated Polyvinyl Chloride (CPVC) and Polyvinyl Chloride (PVC) fill to withstand the high cooling water temperatures. The tower would be situated over a reinforced-concrete basin, which would receive the cooled water flowing through the tower. An underground steel pipe would carry the flow by gravity to a new riprap-paved canal 150 meters long and 30 meters wide that would convey cooled effluent into Castor Creek at a point 150 meters downstream from the present discharge point of the C-Reactor effluent canal.

BB-1 A small water-treatment building would be located near the cooling tower. It
BB-2 would be used to store a chemical biocide (probably sodium hypochlorite) that would be injected into the cooling water stream at the tower inlet to prevent biofouling in the tower system.

This building would contain a system for injecting a dechlorination agent (probably sodium sulfite) into the cooling tower cold water basin. The dechlorinating agent would be injected in sufficient quantities to meet established chlorine effluent limits. Chemical storage tanks and distribution piping would be provided, as would metering pumps and controls, which would be located in the small water-treatment building near the cooling tower.

A new control room located near the cooling tower would contain the necessary switchgear and instrumentation for the operation of all chemical-treatment equipment.

TC The cooling-tower area would be enclosed by a patrol road and fence with personnel and vehicular gates. Access roads would be provided, and parking, loading, and equipment storage areas would be paved at the cooling tower and accessory buildings. Areas around the cooling tower would be regraded and seeded, or, if necessary, covered with stone or paving as appropriate to restore natural surface drainage. An adequate stormwater-drainage system would be constructed inside the fenced area; it would include erosion protection and would discharge into natural drainage ways.

TC Electrical loads for the gravity-feed, natural-draft cooling tower system would be small, consisting primarily of lighting and control equipment. The existing C-Area substations should be adequate, but two new electric lines would be run from C-Area to the cooling tower area along the proposed canal.

Outside lighting and power distribution at the new cooling-tower facilities would be provided. Communications facilities would be extended from the existing C-Area system. Monitoring instrumentation for this cooling system would be installed in the C-Reactor Central Control Room. It would contain monitoring and control instruments that would be connected to instrumentation at the cooling-tower facilities. These instruments would measure such conditions as water temperature at the tower discharge and water flow to the stream. New alarms in the Central Control Room would indicate a high cooling-tower discharge temperature.

Most of the cooling water system construction would be completed with minimal impact on reactor operation. Careful scheduling would ensure that the work

necessary to connect the system with the existing facilities is accomplished during scheduled reactor shutdowns.

Safety practices during construction would be in accordance with applicable safety standards. Occupational exposure to low-level radiation and to chemical contact or inhalation would be minimized by monitoring procedures and by protective equipment and clothing.

Preliminary design evaluations and studies have indicated that optimization of performance and cost savings would be realized by the construction and operation of a natural-draft, once-through cooling tower rather than a mechanical-draft tower as described in the Thermal Mitigation Study (DOE, 1984b) and the draft EIS (DOE, 1986). The description of a mechanical-draft tower would not differ appreciably from that presented above for the natural-draft tower. The major differences would be the size of the tower (e.g., approximately 150 meters high for the natural-draft tower versus 20 meters for the mechanical-draft tower) and the extent of the electrical system upgrade (e.g., the natural-draft tower could require less system upgrade due to the elimination of the fans and motors associated with the mechanical-draft tower).

TC

Thermal Performance

The once-through cooling tower would be designed to enable the discharge to meet the State of South Carolina's Class B water classification standards (i.e., a maximum instream temperature of 32.2°C). This would be accomplished through the design conditions of a 4.4°C approach to a wet-bulb temperature of 27.8°C. In the rare instances when the design wet-bulb temperature was exceeded, the reactor would be operated at reduced power such that the Class B Water Classification standards are always met.

The C-Reactor tower discharge to Four Mile Creek would include the 11.3 cubic meters per second of secondary cooling water flow, less approximately 0.8 cubic meter per second of water evaporated in the tower. The Four Mile Creek flow (at Road A-7), other than the C-Reactor effluent, is approximately 0.6 cubic meter per second. Table 2-4 lists monthly average water temperatures along the cooling water flow path (based on an average of Bush Field meteorological data for 1953 through 1982) with the corresponding ambient stream temperature for the preliminary design of the once-through cooling tower. Additionally, Table 2-4 lists downstream temperatures under extreme (July 1980) summer conditions.

TC

The cooling tower would be designed and operated in such a manner as to meet the maximum weekly average temperature (MWAT) criteria (EPA, 1977) to minimize thermal shock of fish that could occur with a reactor scram (Muhlbaier, 1986). The discharge from the once-through cooling tower would raise the ambient stream temperature in Four Mile Creek above the 2.8°C maximum temperature rise specified in the State of South Carolina's Class B water classification standards. Accordingly, a Section 316(a) study would be performed to demonstrate whether a balanced biological community would be maintained.

BC-14 -110

TC

Table 2-4. Monthly Predicted Mean and Maximum (in Parentheses)
Temperatures (°C) Along Cooling Water Flow
Path of C-Reactor Once-Through Cooling Tower

Location	Temperature for											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Discharge to creek	19(28)	20(28)	23(28)	24(30)	26(30)	28(31)	29(32)	29(32)	28(31)	24(31)	23(29)	21(28)
Four Mile Creek at												
Road A	18(26)	18(26)	21(26)	23(28)	25(29)	28(30)	29(31)	29(31)	27(30)	23(29)	21(27)	19(26)
Road A-13	17(24)	17(24)	21(25)	23(28)	25(29)	28(30)	29(31)	28(31)	27(30)	23(28)	20(26)	18(25)
Swamp delta	15(22)	16(22)	19(23)	22(26)	25(28)	27(30)	28(30)	28(30)	26(29)	22(26)	19(24)	16(22)
Mouth	13(20)	14(20)	18(21)	20(24)	23(27)	26(28)	27(29)	27(29)	25(27)	20(24)	17(21)	14(19)
Ambient creek ^a	9(19)	11(19)	15(24)	19(25)	22(27)	25(31)	25(29)	25(29)	23(28)	21(25)	13(23)	13(18)

a. U.S. Geological Survey data for water year 1985 for station 02197342; Four Mile Creek at Road A-7 (USGS, 1986).

BB-3
BC-14

Resource Utilization

The existing withdrawal of about 11.3 cubic meters per second of water from the Savannah River to C-Reactor would be unchanged for the once-through cooling-tower alternative. Discharges from C-Reactor to the river would be reduced by about 0.8 cubic meter per second due to evaporation, and the total suspended solids concentration would be reduced by settlement in the cooling-tower cold water basin. Chemical biocide added to the cooling water to protect the tower would be neutralized. All discharges would meet State of South Carolina Class B water classification standards.

BB-1
BB-2

Construction of a once-through natural-draft cooling tower system would be completed in approximately 36 months after a 9-month lead design period. The estimated peak contractor manpower requirement, based on preliminary design information, is about 200 persons for C-Reactor, assuming a combined workforce with K-Reactor. The maintenance and operating workforce would be increased by approximately four mechanics. Approximately 35 acres of uplands would be disturbed by all construction activities.

TC

Since the once-through cooling tower system is gravity flow with a natural draft tower, the additional electricity requirements would be only for lighting and chemical feed equipment.

The present peak electrical load in C-Area is about 30.3 megawatts. An insignificant quantity of additional power would be required for lighting and other electrical equipment.

TC

The estimated present-worth cost for the once-through natural-draft cooling tower at C-Reactor with gravity feed would be approximately \$44 million, including production losses (\$42.4 million without production losses). Estimated annual operating costs are \$6.4 million. In addition to these costs, the estimated cost to conduct a Section 316(a) demonstration study is \$1.25 million. Preliminary design criteria suggest a 0.2-percent annual average loss of reactor power attributable to the operation of a once-through cooling-tower system in comparison to the no-action alternative.

AD-1
BC-6

2.2.2.2 Recirculating Cooling Towers

If a closed-cycle, recirculating cooling tower system were constructed, the cooling water discharges from C-Reactor would be conveyed initially in the same manner as in the once-through system (i.e., the same diversion box, pipe, canal, collection box, and pipe under Road 3). However, the natural-draft cooling tower would be somewhat smaller than in the once-through design, and the discharge from this tower would be pumped to a mechanical-draft tower near the existing C-Reactor cooling water reservoir (186-C basin). Figures 2-7 and 2-8, which are based on preliminary design information, show a flow diagram and a site layout, respectively, of this recirculating system.

AD-1
BC-13

The natural-draft cooling tower, when installed with the mechanical-draft tower in series, would be approximately 85 meters in diameter and 120 meters high. Six 1750 horsepower (1300 kilowatt) pumps would be provided to transfer the cooling water from the cold water basin under the first tower through a new steel pipe to the second tower. This 1.8-meter diameter, underground steel pipe would run approximately 2 kilometers from the natural-draft tower

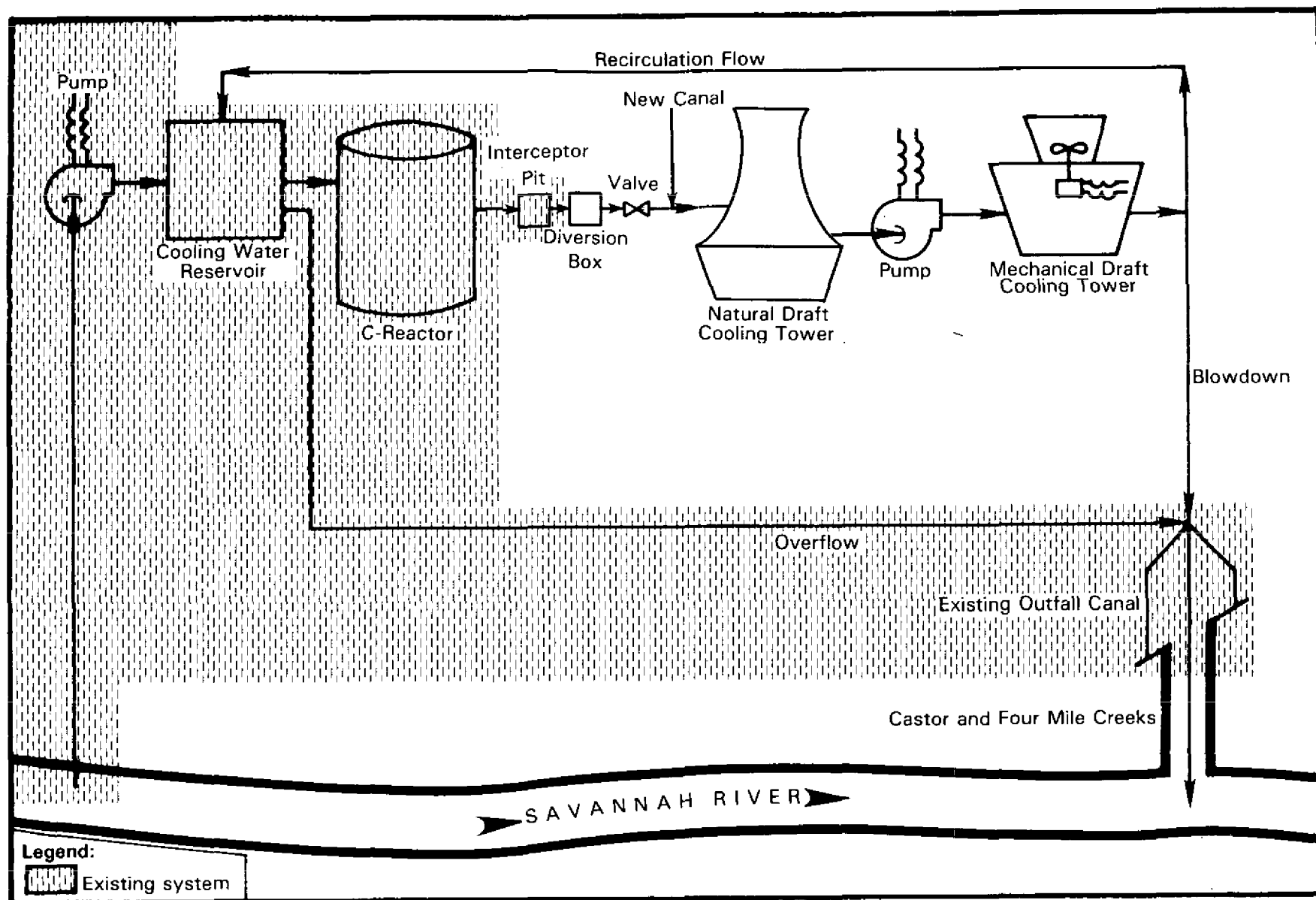


Figure 2-7. C-Reactor Recirculating Cooling Tower System Flow Diagram

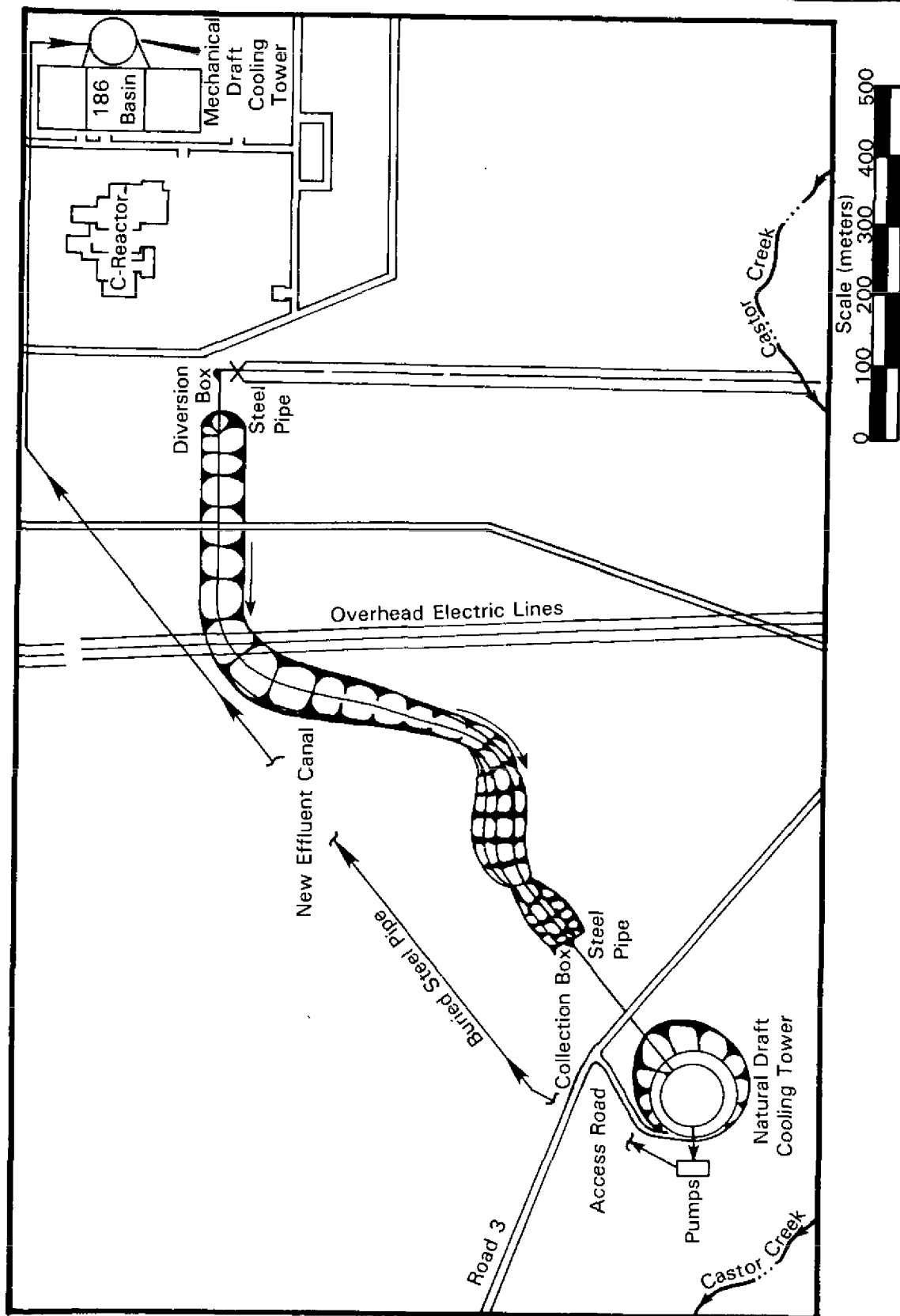


Figure 2-8. C-Reactor Recirculating Cooling Tower System

AO-1
BC-13 | northeasterly under Road 3, along the gravity flow canal, and around the north and east sides of C-Area to the inlet of the mechanical-draft cooling tower. This second tower would be constructed on top of about 5 meters of earth fill, so its discharge could flow by gravity back to the Building 186-C basin for reuse.

The first tower would utilize chlorinated polyvinyl chloride (CPVC) and polyvinyl chloride (PVC) fill to withstand the high cooling water temperatures. The second tower could use standard polyvinyl chloride fill, because the water reaching this tower would have been partially cooled at the first tower. The second tower would be approximately 70 meters in diameter by 20 meters high and would be equipped with 12 fans, each with a 190-kilowatt motor.

BB-1
BB-2 | A small water-treatment building would be located near each cooling tower. These buildings would be used to store a chemical biocide (probably sodium hypochlorite) that would be injected into the cooling water stream to prevent biofouling in the tower system. This would allow for injection of a non-chromated, organic-based, chemical corrosion inhibitor. This chemical has been approved by SCDHEC for use in cooling tower systems and is presently being used at SRP.

Since the recirculating system would be designed to reduce production loss, as well as to meet environmental regulations, no piping has been provided to completely bypass any cooling tower. Internal bypass valves would be included in each cooling tower to divert water directly to the cold water basin. These bypass valves, as well as sectionalizing valves which can isolate parts of the tower fill, would be used for cold weather start-ups and could be used during equipment repairs, if necessary.

AO-1
BC-13 | Whenever water would be recirculated, approximately 0.5 cubic meter per second of the second tower discharge would flow by gravity through a weir to the existing overflow pipeline from Building 186-C. This pipeline flows by gravity back into the existing outfall canal. The flow would then follow the present path of cooling water to Four Mile Creek and the Savannah River. This blowdown flow is necessary to limit the increase in concentrations of solids and chemicals in the cooling water due to evaporation. The blowdown stream would be treated with a dechlorination chemical, probably sodium sulfite, before reaching the existing outfall canal and Castor Creek.

The natural-draft cooling-tower area would be inside a patrol road and fence as described for the once-through system. Access to this area would be from existing Road 3. The existing fence and patrol road along the east side of the C-Reactor area would be relocated to encompass the new mechanical-draft cooling tower and accessories.

A new electrical control room would be located within the C-Reactor production area near the second cooling tower. This room would contain the necessary switchgear and instrumentation for the operation of the cooling tower fans and the chemical-treatment equipment. Another new control room would be constructed near the natural-draft tower for operation of the pumps.

AO-1
BC-13 | The recirculating system would require an upgrade of two sections of 115-kilovolt overhead line totaling 10.5 kilometers. The upgrade would be the

same whether a recirculating system is installed in K-Area or in C-Area or in both areas. Both primary substations in the reactor area would be expanded to handle the increased electrical load.

Dual 13.8-kilovolt electrical supplies would be provided to each location having recirculating pumps or cooling tower fans.

The recirculation system pumps located at the natural draft cooling tower would be supplied from two independent electrical power supplies. Loss of one power supply could cause temporary loss of one half of the pumps depending on electrical power system design. Recirculation flow could be reduced by up to 50 percent during this period; amount of reduction would be dependent on excess head capacity of the pumps. For conservatism, it is assumed that up to 5.1 cubic meters per second could be discharged to the stream if pumps were not provided with automatic transfer on loss of one electrical power supply.

AO-1
BC-13

The present design concept for a recirculating system includes pump start/stop buttons and pump running lights. No interlocks would be provided, or are considered necessary, to scram the reactor.

The C-Reactor central control room would be provided with push buttons and motor running lights for six pumps and 12 fans, discharge effluent (blowdown) flow and temperature indicators, and push buttons and position indicators for two diversion box isolation gates.

Thermal Performance

The recirculating cooling-tower system would be designed for low tower discharge temperatures leading to compliance with the State of South Carolina's Class B water classification standards (i.e., a maximum instream temperature of 32.2°C). The preliminary design parameters of a 2.8°C approach to a 26.7°C wet bulb will assure compliance with this standard, even at the maximum hourly 28°C wet bulb temperature measured at Bush Field from 1953 to 1982.

BC-3
BC-15

For the preliminary design parameters cited above, the blowdown flow to Four Mile Creek would be about 0.5 cubic meter per second at 2.5 cycles of concentration; the corresponding withdrawal from the Savannah River would be about 1.6 cubic meters per second to make up the blowdown and evaporation losses from the system, as well as auxiliary system flows and 186-C basin overflow. Table 2-5 lists monthly average water temperatures for the discharge along the cooling water flow path (based on the preliminary design parameters and meteorological data at Bush Field from 1953 through 1982), along with ambient stream temperatures.

Additionally, Table 2-5 lists downstream temperatures under extreme summer conditions of July 1980. Cooling water discharges from the recirculating cooling-tower system would not always comply with the State of South Carolina's Class B water classification standard that requires that "...free-flowing waters shall not be increased more than 2.8°C above natural temperature conditions...." Accordingly, a Section 316(a) study would be performed to demonstrate whether a balanced biological community would be maintained.

TC

Table 2-5. Monthly Predicted Mean and Maximum (in Parentheses)
 Temperatures (°C) Along Cooling Water Flow
 Path--C-Reactor Recirculating Cooling Towers

Location	Temperature for											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Discharge to creek	14(25)	15(25)	18(26)	20(28)	23(28)	26(29)	27(30)	26(30)	25(29)	20(28)	18(27)	15(26)
Four Mile Creek at												
Road A	9(16)	11(16)	15(18)	18(21)	22(25)	25(27)	27(28)	26(28)	23(25)	17(21)	14(18)	10(15)
Road A-13	8(15)	11(16)	15(18)	18(21)	22(25)	25(28)	27(29)	26(28)	23(25)	17(21)	14(17)	9(15)
Swamp delta	8(15)	10(15)	14(17)	19(21)	22(26)	26(28)	27(29)	27(29)	24(26)	17(20)	13(16)	9(14)
Mouth	7(14)	10(14)	14(17)	17(19)	20(23)	24(25)	25(26)	25(25)	21(23)	15(19)	13(15)	8(13)
Ambient creek ^a	9(19)	11(19)	15(24)	19(25)	22(27)	25(31)	25(29)	25(29)	23(28)	21(25)	13(23)	13(18)

a. U.S. Geological Survey data for water year 1985 for station 02197342; Four Mile Creek at Road A-7 (USGS, 1986).

BC-3
BC-15

Resource Utilization

C-Reactor presently receives approximately 11.3 cubic meters of cooling water per second from the Savannah River. This continuous flow passes through the reactor heat exchangers and discharges down Castor Creek and Four Mile Creek back to the Savannah River. If the recirculating cooling-towers alternative were implemented, the discharge from C-Reactor would be reduced to about 1 cubic meter per second. The amount of water removed from the river would be reduced to about 1.6 cubic meters per second.

TC

This alternative would be constructed in approximately 42 months after a 9-month design period. The estimated peak manpower requirement for C-Reactor is 300 persons, assuming a combined workforce with K-Reactor. The maintenance and operating workforce would be increased by approximately six mechanics. Approximately 60 acres of uplands would be disturbed by all construction activities.

TC

TC

The present peak electrical load for C-Area is about 30.3 megawatts. The electrical load would be decreased approximately 6.4 megawatts because of the 85 percent reduction in electrical load to pump water from the Savannah River to the 186-C basin. The total yearly energy reduction caused by this project would be the equivalent of the electricity produced by the combustion of approximately 12,800 barrels of crude oil.

TC

The estimated present-worth cost of this alternative would be approximately \$90 million including production losses (\$58 million without production losses). Estimated annual operating costs are \$4.4 million. In addition to these costs, the estimated cost to conduct a Section 316(a) demonstration study is \$1.25 million. Preliminary design criteria suggest a 3.7-percent annual average loss of reactor power attributable to the operation of a recirculating cooling-tower system, in comparison to the no-action alternative.

AD-1
BC-6

2.2.2.3 No Action - Existing System

The existing once-through cooling water system for C-Reactor withdraws approximately 11.3 cubic meters of water per second from the Savannah River at the 1G and 3G pumphouses. From these pumphouses the water passes through an interconnected network of underground pipe to the Building 186-C basin which has a capacity of approximately 95,000 cubic meters.

The cooling water is drawn by gravity through the reactor heat exchangers to an interceptor pit and then through an underground steel pipe. The water flows to a reinforced-concrete headwall at the existing C-Reactor cooling water outfall canal. This canal, lined with concrete and stone riprap, dissipates the energy of the discharge as it flows to Castor Creek, a tributary of Four Mile Creek. The discharge flows along Castor Creek and Four Mile Creek and into the Savannah River about 8 kilometers downstream from the D-Area powerhouse and the river-water pumping stations.

C-Reactor discharges approximately 11.3 cubic meters of cooling water per second at an average temperature of 70°C to 77°C. This flow includes 10.5 to 10.9 cubic meters per second from the reactor heat exchangers and 0.3 to 0.6 cubic meter per second of service water and other flows. It does not include any overflow from the 186-C basin, which is normally 0.2 cubic meter

per second but can be as high as 0.95 cubic meter per second. This overflow is always at ambient water temperature; therefore, it adds no heat load. Estimated annual operating costs for the no-action alternative are \$6.2 million.

Thermal Performance

TE

The temperature of the secondary cooling-system water at C-Reactor normally ranges between 47°C (average summer) and 61°C (average winter) above ambient. Virtually the entire flow withdrawn from the Savannah River is discharged to Four Mile Creek, with the auxiliary systems water mixing with the heated secondary cooling water.

The temperature of the effluent water varies with the temperature of the river water, although the seasonal fluctuations of the latter are moderated by an inverse relationship between intake water temperature and temperature increase. Table 2-6 indicates monthly average and summer extreme temperatures along the cooling water flow path. The downstream heat-loss characteristics are based on meteorological data from Bush Field between 1953 and 1982; the extreme summer conditions are for July 1980. Table 2-6 also lists ambient creek temperatures.

Table 2-6 illustrates that the State of South Carolina's Class B water classification standard that specifies a maximum instream temperature of 32.2°C is exceeded at all times along points in the creek during C-Reactor operation. The heat loss along the creek implies an evaporation rate of approximately 0.5 cubic meter per second between the discharge and the delta - less than 5 percent of the discharge flow.

2.2.3 D-AREA POWERHOUSE ALTERNATIVES

The alternatives for the D-Area coal-fired powerhouse are increased flow with mixing (DOE's preferred alternative), direct discharge to the Savannah River, and no action. The following sections describe these alternatives.

2.2.3.1 Increased Flow with Mixing (Preferred Alternative)

The D-Area powerhouse uses water pumped from the Savannah River for cooling. Most of this water is discharged from the condensers into an excavated canal that flows into Beaver Dam Creek about 1700 meters upstream from the Savannah River swamp.

A closed-loop recirculation system utilizing an existing cooling tower can provide an alternative cooled water supply for one of the four units.

During current normal operations, water is pumped by three of six pumps located in the Building 681-5G pumphouse, situated on a small inlet cove about 1.6 kilometers upstream from the mouth of Beaver Dam Creek. The rated capacity of each pump is about 0.8 cubic meter per second, with a maximum sustained flow for all six pumps of about 4.5 cubic meters per second. The water flows through an underground pipeline to a raw-water receiving basin in Building 483-1D. Excess water not utilized in the powerhouse and 400-Area water-treatment plant overflows a weir to mix with the powerhouse effluent stream before discharging into the D-Area outfall canal (see Figure 2-9). The

Table 2-6. Monthly Predicted Mean and Maximum (in Parentheses)
Temperatures (°C) Along C-Reactor Cooling Water Flow
Path: No Action (Existing System)

Location	Temperature for											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Discharge to outfall	69(70)	69(71)	70(72)	71(73)	72(73)	73(74)	74(75)	74(75)	73(75)	72(74)	71(73)	70(72)
Four Mile Creek at												
Road A	49(51)	49(51)	50(52)	53(55)	55(57)	57(58)	57(58)	58(58)	57(58)	55(57)	52(53)	50(52)
Road A-13	42(45)	42(44)	44(45)	46(48)	49(51)	50(51)	51(52)	51(52)	50(51)	49(50)	45(47)	43(45)
Swamp delta	32(35)	33(35)	34(36)	38(39)	40(42)	42(43)	43(43)	43(44)	42(42)	39(40)	35(37)	33(35)
Mouth	24(27)	24(27)	27(29)	30(32)	33(35)	35(36)	36(37)	36(37)	34(35)	31(33)	27(29)	25(27)
Ambient creek ^a	9(19)	11(19)	15(24)	19(25)	22(27)	25(31)	25(29)	25(29)	23(28)	21(25)	13(23)	13(18)

a. U.S. Geological Survey data for water year 1985 for station 02197342; *Four Mile Creek at Road A-7* (USGS, 1986).

BB-3
BC-14

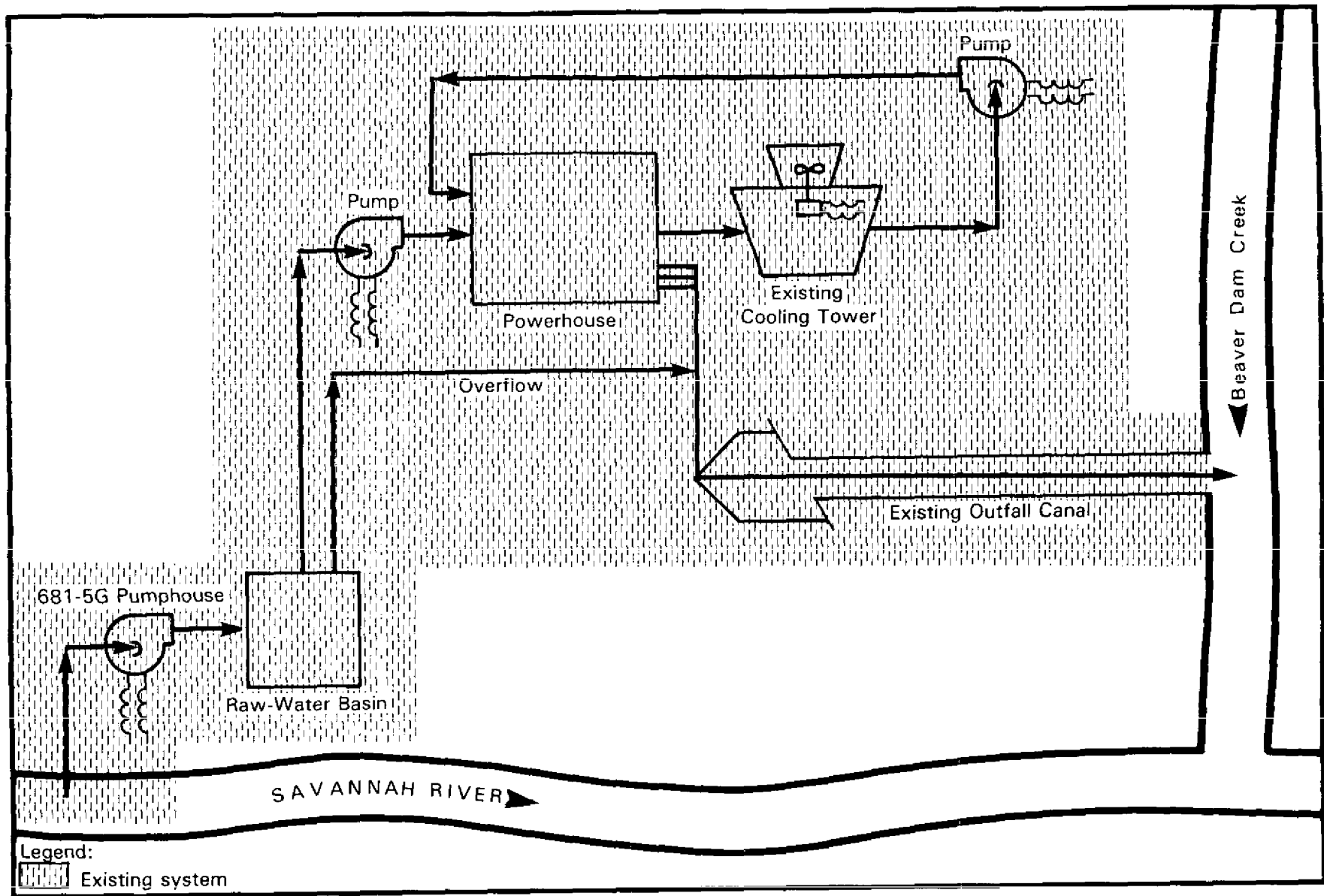


Figure 2-9. D-Area Existing System Flow Diagram

corresponding flow rate in Beaver Dam Creek at the SRP Health Protection Department monitoring station using various numbers of pumps is as follows: three pumps, 2.6 cubic meters per second; four pumps, 3.5 cubic meters per second; five pumps, 4.0 cubic meters per second; and 6 pumps, 4.5 cubic meters per second.

The increased-flow-with-mixing cooling water alternative would require the intermittent use of four to six pumps to provide a total flow (as much as 4.5 cubic meters per second at the HP monitoring station) of Savannah River water to the raw-water receiving basin. The overflow rate would be adjusted to maintain a maximum instream temperature of 32.2°C. The temperature would be monitored by an automatic monitoring station, maintained at the compliance point, and displayed in the powerhouse control room. The existing one-unit recirculation system with a cooling tower would continue to operate as at present.

Because sufficient pumping capacity is already available in the Building 681-5G pumphouse, no major new construction would be necessary to implement increased flow with mixing, and the plan could be implemented immediately. However, increased operation of the existing pumps would require circulation of more water from the Savannah River, consumption of more electricity, and a slight increase in maintenance cost.

Thermal Performance

The temperature of the D-Area cooling water withdrawn from the Savannah River rises as it passes through the powerhouse condensers. The flow from one of the four powerhouse condensers normally is directed to a cooling tower (design conditions for the cooling tower are: hot-water temperature, 40°C; wet-bulb temperature, 24°C; discharge temperature, 32°C). The blowdown flow from the cooling tower is negligible compared to the flow through the once-through system. The rate of evaporation from the cooling tower at design conditions is approximately 0.01 cubic meter per second; thus, essentially all of the water (99.5 percent at normal flow) withdrawn from the Savannah River for D-Area cooling is discharged to Beaver Dam Creek.

The temperature of the cooling water discharge from the D-Area powerhouse would vary due to variations in the temperature of the water withdrawn from the Savannah River and powerhouse loadings. Table 2-7 shows monthly average water temperatures along the cooling water flow path (based on meteorological data for Bush Field from 1953 through 1982) along with the corresponding ambient stream temperatures, assuming operation of as many as five pumps (4.0 cubic meters per second) during extreme summer conditions. Discharge temperatures are based on measured values from 1985 and 1986.

TC

Table 2-7 indicates that under average seasonal meteorological conditions the discharge to the creek from the operation of the D-Area powerhouse will meet the State of South Carolina's Class B water classification standard of a maximum instream temperature of 32.2°C, provided that, under extreme summer conditions, the flow to the raw-water basin will be increased from 2.6 to as high as 4.0 cubic meters per second to decrease the discharge temperature. The current discharge from the D-Area powerhouse would continue to exceed the Class B water classification standard of a maximum 2.8°C ambient rise in

TC

Table 2-7. Monthly Predicted Mean and Maximum (in Parentheses)
Temperatures (°C) Along Cooling Water Flow
Path of D-Area Powerhouse for Increased Flow
with Mixing Alternative

Location	Temperature for											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Discharge to creek	18(27)	16(22)	21(27)	24(29)	28(30)	29(32)	28(30)	28(31)	27(31)	27(32)	26(31)	19(31)
Swamp delta	17(25)	16(21)	20(26)	24(28)	27(30)	28(31)	28(30)	28(31)	27(30)	26(31)	24(29)	18(28)
Mouth	13(20)	14(19)	17(21)	20(24)	24(27)	26(29)	27(29)	27(29)	25(27)	21(26)	19(23)	14(21)
Ambient creek ^a	8(15)	9(14)	12(17)	15(20)	19(22)	21(25)	23(27)	23(26)	23(26)	20(23)	17(22)	12(18)

a. Average U.S. Geological Survey data for water years 1976 to 1985 for station 02197320; Savannah River near Jackson, South Carolina (USGS, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986).

BB-3
BC-14

stream temperature. A Section 316(a) demonstration study would be performed to show whether a balanced biological community would be maintained.

Resource Utilization

The current flows in Beaver Dam Creek downstream from the D-Area discharge canal average approximately 2.6 cubic meters per second. During extreme summer conditions, the implementation of this alternative would increase that flow to a maximum of 4.0 cubic meters per second, and would temporarily affect an estimated 4 acres each of uplands and wetlands.

TC

No appreciable change in the chemical characteristics of the effluent is expected because no chemicals would be used in implementing this alternative.

Each operating pump at the Building 681-5G pumphouse consumes approximately 8700 kilowatt-hours of electricity per day. When all four D-Area units are operating, three pumps are required to supply cooling water. Assuming that additional pumping is continued all day whenever the discharge water temperature exceeds 31°C, the estimated increase in electric-power consumption is approximately 6 percent. The amount of electricity used at this pumphouse is a small portion of the overall SRP use. Therefore, the incremental increase in the use of electricity for D-Area would be extremely small.

The estimated increase in annual operating cost for incremental electric consumption is \$30,000. In addition, the cost to conduct a Section 316(a) demonstration study is estimated at \$1.25 million.

2.2.3.2 Direct Discharge to Savannah River

Another alternative for the cooling water discharge from the D-Area powerhouse is the extension of the existing discharge piping to the Savannah River (Figures 2-10 and 2-11). The existing cooling water system would continue to pump the present flow from the Building 681-5G pumphouse to the Building 483-1D raw-water receiving basin and through the condensers. The existing cooling tower would continue to operate as a recirculating system for one condenser. However, the existing discharge headers from the condensers would be intercepted by a new interceptor sump. From this point a new underground pipe about 1.5 kilometers long would enable the water to flow by gravity to the Savannah River, about 91 to 152 meters downstream from the Building 681-5G pumphouse. The existing effluent discharge canal would no longer receive cooling water, but would continue to receive overflows from the raw-water basin.

The new pipeline would be located between the existing supply pipeline from the pumphouse and the existing power lines running to the pumphouse. It would cross under an unnamed stream and extend through approximately 400 meters of swamp before reaching the river.

The discharge structure at the river would be a sparging type extending into the river about 90 to 150 meters downstream of the 5G intake structure to avoid any recirculation. The discharge structure would promote mixing cooling water effluent with the river water flow.

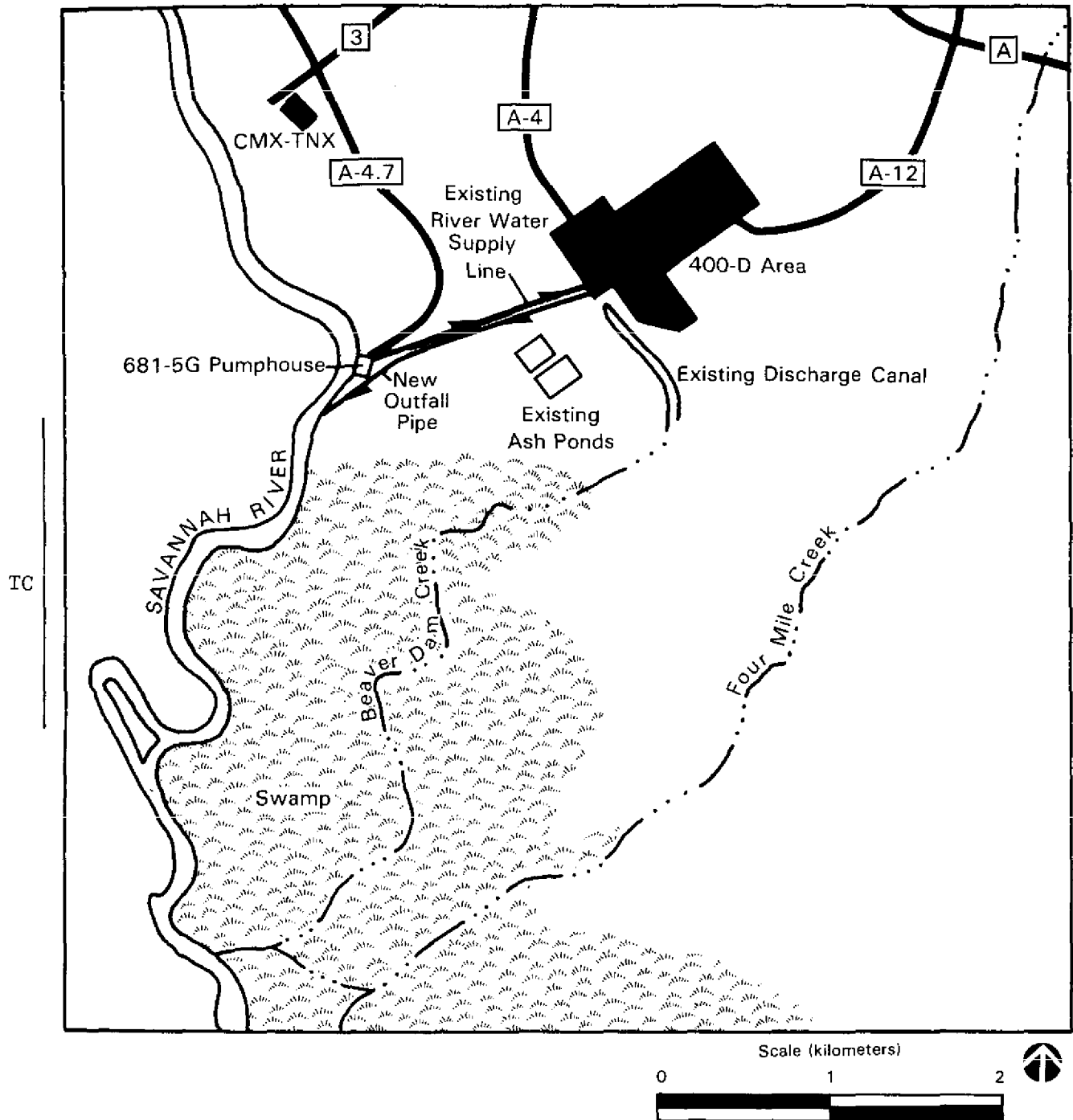


Figure 2-10. D-Area Discharge to Savannah River Alternative

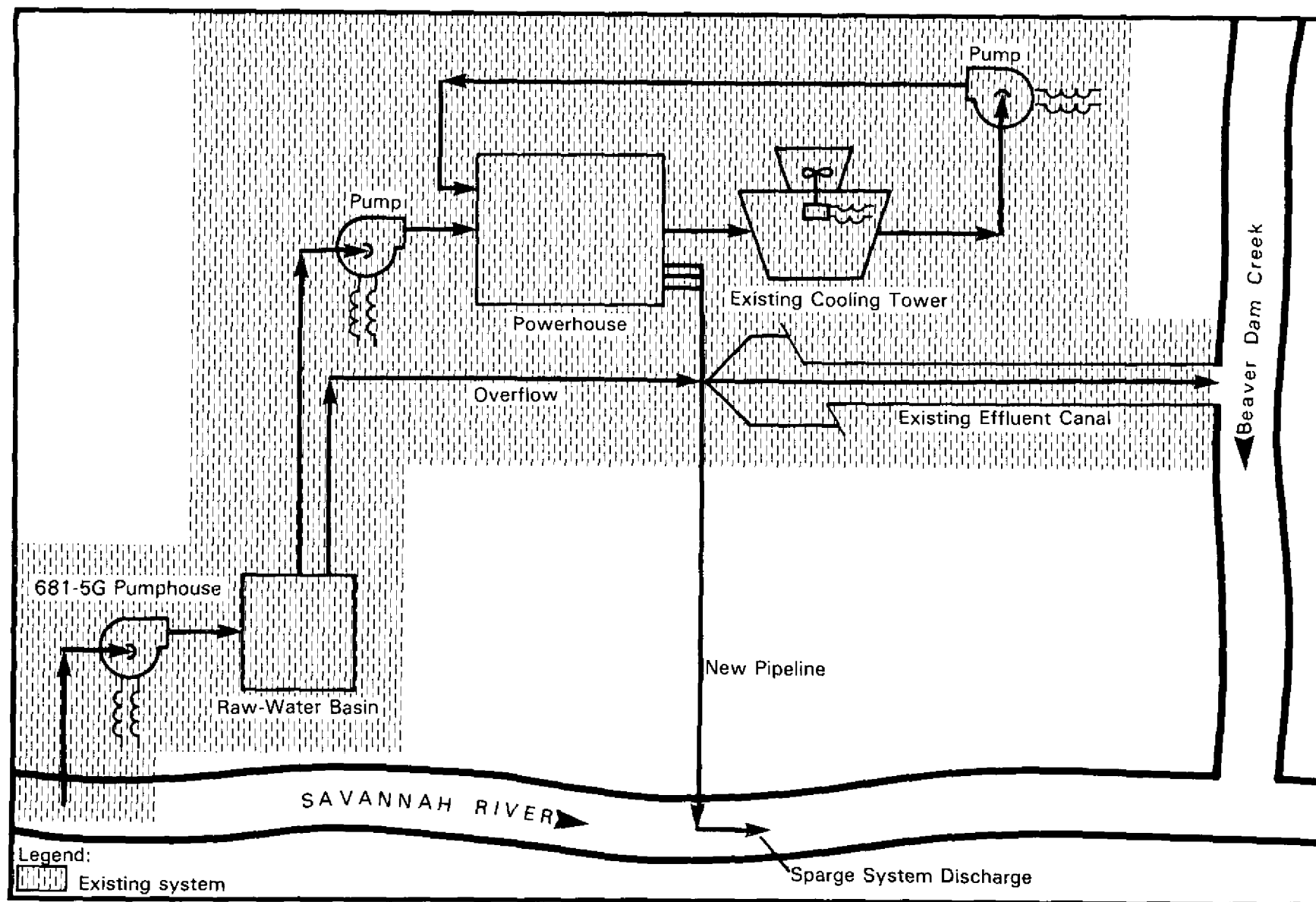


Figure 2-11. D-Area Direct Discharge to Savannah River Flow Diagram

Thermal Performance

With the direct-discharge alternative, the temperature of the D-Area powerhouse cooling water discharge would vary due to variations in the temperature of water withdrawn from the Savannah River and powerhouse loadings. Table 2-8 shows the seasonal variation in river and discharge temperatures and indicates that these temperatures for all average seasonal conditions are less than 32.2°C, assuming an 8°C rise in the temperature of cooling water withdrawn from the Savannah River as it passes through the powerhouse condensers. During extreme summer conditions the discharge temperature is 36°C.

In accordance with the State of South Carolina's regulations for water classifications and standards, the ambient water temperatures of Class B waters may not be increased by more than 2.8°C or exceed a maximum of 32.2°C as a result of thermal discharges, unless a mixing zone has been established. The purposes of the mixing zone are to allow the safe passage of aquatic organisms and to allow protection and propagation of a balanced indigenous population of aquatic organisms. This zone is to be based on critical flow conditions.

Table 2-8 lists the percentages of total cross-sectional areas and widths corresponding to temperatures of less than 2.8°C and temperatures of less than 32.2°C. Even under summer extreme conditions, the zone of passage would encompass 93 percent (width) and 99 percent (cross-sectional area) of the Savannah River.

Resource Utilization

The existing flow of water from the Savannah River to the D-Area powerhouse would be unchanged. Flow in the existing effluent canal, however, would be reduced from the current average of about 2.6 cubic meters per second to about 0.5 cubic meter per second during normal powerhouse operations. At maximum powerhouse operations, the flow in the canal would be about 0.3 cubic meter per second. This flow would increase to about 0.9 cubic meter per second when the powerhouse is shut down. Beaver Dam Creek would receive intermittent rainfall runoff and groundwater seepage in addition to this reduced flow. Chemical and suspended-solids characteristics of the cooling water effluent would be unchanged.

Connection of the new outfall pipe to the existing condenser outlet piping would require temporary shutdown of units operating in a once-through mode at the time of connection.

Construction of the pipeline to the river could be accomplished in approximately 22 months with a peak contractor manpower requirement of 40 persons. No increase in the maintenance or operation workforce would be necessary. The 22-month construction schedule includes the building of a new temporary road, a support structure for the pipeline through low-lying areas, and the submission and approval of necessary permits. An estimated 5 acres of uplands and 1 acre of wetlands would be disturbed by construction. Any excess excavated material would be removed from the construction area and deposited at an approved spoil site so that natural drainage would not be disturbed.

Construction of the sparge system would disturb the river bank, and it would be restored to protect the floodplain system downstream.

Table 2-8. Temperatures and Passage Zone Sizes for D-Area
Powerhouse Direct Discharge Into Savannah River^a

Location or area	Winter average	Spring average	Summer average	Summer extreme ^b
Temperature (°C)				
Withdrawal from river	8	17	23	28
Discharge to river	16	25	31	36
Maximum river cross-sectional area (percent of total) having temperature (°C) less than				
2.8 (excess)	99.7	99.7	99.5	99.3
32.2 (absolute)	100	100	100	99.7
Maximum river width (percent of total) having temperature excess (°C) less than				
2.8 (excess)	95	95	94	93
32.2 (absolute)	100	100	100	96

- a. Based on results of thermal modeling as described in Appendix B.
b. Modeling parameters for summer extreme use minimum 7-day average flow with an average frequency of once in 10 years (7Q10) for the Savannah River.

BB-3
BC-14

The capital cost of this alternative would be approximately \$14 million. There would be \$50,000 additional annual operating costs associated with this alternative.

2.2.3.3 No Action - Existing System

Under the no-action alternative, the existing withdrawal of Savannah River water and discharge to Beaver Dam Creek would continue. An average of about 2.6 cubic meters per second of water would be pumped from the Savannah River to the D-Area powerhouse for cooling and then discharged from the cooling system to Beaver Dam Creek.

Thermal Performance

Table 2-9 lists monthly average water temperatures along the cooling water flow path (based on meteorological data at Bush Field from 1953 through 1982), along with corresponding ambient stream temperatures; discharge temperatures are based on 1985 and 1986 measurements.

Table 2-9. Temperatures ($^{\circ}\text{C}$) Along Cooling Water Flow
Path--D-Area Powerhouse--No Action (Existing System)

Location	Temperature for											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Discharge to creek	18(27)	16(22)	21(27)	24(29)	28(32)	29(34)	28(33)	28(33)	27(33)	27(34)	26(33)	19(31)
Swamp delta	17(25)	16(21)	20(26)	24(28)	27(31)	28(33)	28(33)	28(32)	27(32)	26(32)	24(30)	18(28)
Mouth	17(22)	17(21)	20(24)	24(27)	27(29)	29(31)	30(31)	29(31)	28(30)	25(29)	22(27)	18(23)
Ambient creek ^a	8(15)	9(14)	12(17)	15(20)	19(22)	21(25)	23(27)	23(26)	23(26)	20(23)	17(22)	12(18)

a. Average U.S. Geological Survey data for water years 1976 to 1985 for station 02197320; Savannah River near Jackson, South Carolina (USGS, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986).

BB-3
BC-14

Table 2-9 indicates that during average conditions, the discharge to the creek will meet the maximum instream temperature standard of 32.2°C. However, under extreme meteorological conditions, the discharge temperature could be 2°C greater than that allowed by the State of South Carolina's Class B water classification standard. The discharge from the D-Area powerhouse would exceed the Class B water classification standard of a maximum 2.8°C ambient rise in stream temperature.

2.3 COMPARISON OF ALTERNATIVES

For each of the three facilities, selection of the no-action alternative would result in a continuation of present cooling water discharges that would not comply with the State of South Carolina's Class B water classification standard of a maximum instream temperature of 32.2°C. The construction and operation of either once-through or recirculating towers for K- and C-Reactors and implementation of either increased flow with mixing or construction and operation of direct discharge to the Savannah River for the D-Area powerhouse would result in discharges that would comply with this standard. Construction and operation of once-through or recirculating cooling towers for K- and C-Reactors and implementation of increased flow with mixing for the D-Area powerhouse would also require the conduct of Section 316(a) studies to determine whether a balanced biological community would be maintained, because discharges from these alternatives would exceed the Class B water classification standard of a maximum instream ambient temperature rise of 2.8°C. The following comparison discusses the major differences that would occur from the implementation of each of the alternatives.

BB-3

2.3.1 ALTERNATIVES FOR K-REACTOR

Either of the two cooling-tower alternatives would reduce significantly the thermal impacts in Pen Branch and the Savannah River swamp. The major environmental difference between these alternatives is that the recirculating cooling towers would withdraw less water from the river (about 1.6 cubic meters per second) and release less to the creek (about 1 cubic meter per second) than the once-through tower (about 11.3 and 10.5 cubic meters per second, respectively). This would result in reduced entrainment losses of fish eggs and larvae and reduced impingement losses of adult and juvenile fish with the recirculating towers. The reduced flow in Pen Branch and its delta would also result in successional reestablishment of a greater amount of wetlands than would occur with the once-through alternative; on the other hand, the lower flow would also reduce the existing amount of aquatic habitat in the creek and parts of the swamp than would occur with the once-through tower.

TE

Both alternatives would allow the reestablishment of aquatic faunal and floral communities, and spawning and foraging in presently uninhabited areas. However, the once-through cooling-tower alternative would exhibit a greater amount of water-level fluctuation, causing some stress to aquatic organisms.

The implementation of recirculating cooling towers would cause fewer thermal effects than once-through towers; however, the flooded habitat area would be smaller. Most aquatic communities would benefit from the reduced flow and decreased magnitude of the water-level fluctuations with the implementation of a recirculating system. Neither alternative would cause cold shock, because

TC

both would meet the Maximum Weekly Average Temperature criteria for winter shutdowns would be met. Dissolved-solids concentrations in the discharge would be higher with the recirculating alternative because of cycles of concentration; however, total suspended solids discharged would be greatly reduced.

The fluctuating water levels and high flow rates associated with the once-through alternative could destroy nests, eggs, and hibernation sites of the American alligator. This alternative would also minimize the availability of preferred foraging habitat for the endangered wood stork. The implementation of the recirculating cooling tower would greatly improve habitat quality for the American alligator and the wood stork. Because of the reduced flow, eggs, nests, and hibernation sites of the American alligator should not be affected adversely.

TC

The following relative rankings of future wildlife effects were determined for the various cooling water alternatives (Mackey et al., 1987). Effects to terrestrial wildlife from the construction of the once-through and recirculation cooling towers are essentially equal, because either type of tower would be constructed at the same locations, and pipeline and other support facilities would affect essentially the same locations. Small stream fish species would benefit more from the recirculation alternative in the upper reaches of the creeks. In the middle and lower reaches, species such as the catfish and sunfish would benefit more from the once-through alternative. In the deep swamp environment, fish that are more likely to use the swamp during the spawning period would benefit more from the recirculation alternative. In the Savannah River swamp, wading birds would benefit more from the recirculation alternative. Overwintering waterfowl such as the mallard would benefit more either from present SRP operations or from the once-through cooling-tower alternative; these alternatives either maintain the existing marsh-type environment in the swamp for wintering waterfowl or permit the expansion of this type of habitat as deep swamp wetlands (cypress/typelo) are reduced and converted to more open wetlands due to releases of high flows of cooling water effluent.

AD-1
BC-13

The impacts of both systems on air quality would be similar; however, because a recirculating cooling-tower system includes two towers operated in series with 2.5 cycles of concentration, the maximum ice accumulation near the towers would be greater for the recirculating system (7 millimeters versus less than 1 millimeter), as would the maximum annual deposition of total solids (2.2 kilograms per acre per year within about 2 kilometers from the tower versus 0.5 kilogram per acre per year for the once-through tower). Because these deposition rates are far below the levels that can cause reduced vegetation productivity (83 kilograms per acre per year), no impacts on vegetation or wildlife are expected.

TC
BC-22

The operation of the once-through cooling tower would not cause any significant changes in the remobilization of radionuclides contained in the Pen Branch bed, because the flow in the creek would remain essentially unchanged. The operation of recirculating towers would result in a calculated decrease of about 0.12 curie of cesium released to the Savannah River over a year due to the reduced flow. The implementation of either the once-through cooling tower or recirculating cooling towers would slightly reduce the radiological doses to the maximum individual and the population compared with the existing direct-discharge system, which are presently well within standards. The

decrease in maximum individual and collective (population) doses, however, would be greater for recirculating cooling towers than for once-through towers.

The once-through cooling-tower system for K-Reactor would cost approximately \$47 million less to construct than recirculating cooling towers. However, recirculating towers would cost approximately \$2 million less to operate each year. In addition, recirculating cooling towers would require approximately 6 months longer to construct. The implementation of recirculating cooling towers would lower reactor power by 3.7 percent, in comparison to only 0.2 percent with the once-through system. Costs to conduct a Section 316(a) Demonstration study would be the same for both alternatives.

Table 2-10 provides a summary comparison of the alternatives for K-Reactor.

2.3.2 ALTERNATIVES FOR C-REACTOR

The comparisons of impacts of the two cooling-tower alternatives are similar to those associated with K-Reactor. The recirculating cooling towers would allow the reestablishment of approximately 1000 acres of wetlands, compared to more limited revegetation with the once-through cooling-tower alternative; however, there would be less aquatic habitat in the creek and swamp because of lower flow associated with the recirculating system.

BC-19
BD-3

The implementation of either system would result in cooling water discharges that are in compliance with the 32.2°C Class B water classification standard for temperature and dissolved oxygen. Both systems would improve habitat over existing conditions for the alligator and wood stork.

Similar impacts to air quality and noise would be expected from both systems. However, the recirculating cooling-tower system would include two towers in series with 2.5 cycles of concentration; these towers would cause greater ice buildup (7 millimeters versus less than 1 millimeter). Salt deposition would also be greater with the recirculating towers (2.2 kilograms per acre per year within about 2 kilometers) than with a once-through system (0.5 kilogram per acre per year). Because these deposition rates are far below the levels that can cause reduced vegetation productivity (83 kilograms per acre per year), no impacts on vegetation are expected.

The remobilization of radionuclides and dose effects would be similar to those described for K-Reactor. The recirculating cooling towers would result in a calculated decrease in the amount of cesium released to the Savannah River by about 0.21 curie per year. Both the maximum individual and the population doses would decrease through the implementation of either the once-through cooling-tower or the recirculating-cooling-towers alternative.

BC-22

Table 2-11 provides a summary comparison of the alternatives for C-Reactor.

2.3.3 ALTERNATIVES FOR D-AREA

The implementation of the increased-flow alternative would not alter the flow or temperature of Beaver Dam Creek except during those periods (May through September) when the system could be activated to maintain water temperatures below 32.2°C. Therefore, the existing aquatic habitat would be maintained, and its value to alligators, fish, and other aquatic organisms would be

Table 2-10. Comparison of Cooling Water Alternatives for K-Reactor
(page 1 of 5)

		Impacts	No action ^a	Once-through cooling tower (preferred alternative ^b)	Recirculating towers
TC		SCHEDULE FOR IMPLEMENTATION	Current	Construction of this system would require about 36 months after a 9-month design period.	Construction of this system would require about 42 months after a 9-month design period.
		PRELIMINARY PRESENT-WORTH (MILLION \$)			
AD-1 BC-6		- including production loss	\$0	\$43.0	\$89.8
		- excluding production loss	\$0	\$41.4	\$58.0
		ESTIMATED OPERATING COST (MILLION \$ PER YEAR)	\$6.2	\$6.4	\$4.4
AD-1 BC-13		SOCIOECONOMICS	No additional work force required.	Peak construction workforce of 200 persons; four additional mechanics required for operation.	Peak construction workforce of 300 persons; six additional mechanics required for operation.
		WATER WITHDRAWAL AND DISCHARGE RATES	About 11.3 cubic meters per second would continue to be withdrawn from the Savannah River and discharged into Indian Grave/Pen Branch.	Withdrawal the same as for no action; discharge to Indian Grave/Pen Branch would be about 92% of that for no action or 10.5 cubic meters per second.	Withdrawal of river water would be about 4.5% of that for no action or 1.6 cubic meters per second. Discharge to Indian Grave/Pen Branch would be about 10% of that for no action or about 1 cubic meter per second.
BB-1 BB-2 BB-3 BC-10		WATER QUALITY	Dissolved oxygen concentrations are below standards intermittently during the summer and total suspended solids are slightly higher than ambient stream levels.	State Class B water classification standards for dissolved oxygen concentrations would be met. There would be some reduction in total suspended solids.	State Class B water classification standards for dissolved solids concentrations would be higher than no action or once-through cooling tower because of cycles of concentration; however, total suspended solids discharged would be greatly reduced.

Table 2-10. Comparison of Cooling Water Alternatives for K-Reactor
(page 2 of 5)

Impacts	No action ^a	Once-through cooling tower (preferred alternative ^b)	Recirculating towers
TEMPERATURE AND FLOW EFFECTS	Water temperature in Indian Grave/Pen Branch would exceed State Class B water classification standards. There would continue to be few aquatic organisms in the thermal areas of Pen Branch and its delta. A thermal barrier will prevent aquatic movement in Indian Grave/Pen Branch. Fish spawning in the creek and delta would remain reduced. There would continue to be a potential for cold shock during the winter.	State Class B water classification standards for temperature (32.2°C) would be met; a Section 316(a) Demonstration study will be performed for exceedances of 2.8°C rise in ambient stream temperatures. Aquatic organisms would become established in present thermal areas. Thermal barrier would be removed. Creek and delta would be opened to fish spawning and foraging. There would be no potential for cold shock because MWAT (EPA, 1977) criteria would be met. Water levels would continue to fluctuate.	State Class B water classification standards for temperature (32.2°C) would be met; a Section 316(a) study would also be performed. Similar mitigation of thermal effects that would occur with once-through towers, except habitat area for spawning and foraging would be smaller because of reduced flow; magnitude of water level fluctuations would be less.
ENTRAINMENT/IMPINGEMENT	Water withdrawal would continue to cause entrainment losses of about 13.4×10^6 fish eggs and larvae and the loss of about 2942 fish to impingement annually.	Effects would be about the same as for no action.	Annual entrainment and impingement losses would be reduced to about 2.0×10^6 fish eggs and larvae and 427 fish, respectively.
HABITAT	Flow and temperature impacts would continue to result in the loss of about 26 acres of wetlands each year.	Wetland losses would decrease; some successional revegetation would occur. About 25 acres of uplands would be affected by construction.	Wetland losses would essentially cease and about 500 acres of wetlands would successively revegetate; about 50 acres of uplands would be affected by construction.
SOLIDS DEPOSITION	None.	Maximum annual total-solids deposition within about 2 km of the tower would be	Maximum annual total-solids deposition within about 2 km of the tower would be about

BB-3

BD-5

BC-19
BD-3

TC

Table 2-10. Comparison of Cooling Water Alternatives for K-Reactor
(page 3 of 5)

Impacts	No action ^a	Once-through cooling tower (preferred alternative ^b)	Recirculating towers
		about 0.5 kilogram per acre per year. Deposition rates are far below levels that cause reduced vegetation productivity.	2.2 kilograms per acre per year. Deposition rates are far below levels that cause reduced vegetation productivity.
ENDANGERED SPECIES	Thermally affected areas of Pen Branch and swamp would continue to be too hot for alligators. Low fish densities and high water levels limit forage value for wood stork. No impacts on shortnose sturgeon and red-cockaded woodpecker.	Alligator habitat would be improved by lower water temperatures. Some improvement of wood stork foraging habitat would result from increased fish concentrations although continued high flows would maintain deep water conditions. No impacts on shortnose sturgeon, red-cockaded woodpecker, and bald eagle.	Some alligator habitat would be available; however, lower flows would decrease potential habitat area resulting in less improvement than with once-through towers. Potential for improvement of wood stork habitat would be increased due to lower water levels in the creek and delta. No impacts on shortnose sturgeon, red-cockaded woodpecker, and bald eagle.
AIR QUALITY	No impacts.	Construction would result in temporary small increases in carbon monoxide and hydrocarbons from engine exhaust. Also some transient increases in airborne dust.	Construction impacts would be similar to those for once-through tower.
		Maximum annual-mean frequency of reduced ground-level visibility to less than 1000 m would be about 2 hours per year.	Reduction in ground-level visibility would be about 2 hours per year.
		Maximum ice accumulation on horizontal surfaces would be no more than 1 mm.	Maximum ice accumulation on horizontal surfaces would be no more than 1 mm beyond 0.8 km of the tower. Maximum predicted thickness

Table 2-10. Comparison of Cooling Water Alternatives for K-Reactor
(page 4 of 5)

Impacts	No action ^a	Once-through cooling tower (preferred alternative ^b)	Recirculating towers	
			would be 7 mm, occurring within 0.4 km of the tower with a total frequency of 88 hours per winter season.	TC
		Maximum occurrence of visible plumes would be about 180 hours per year within 0.4 km of the tower and 30 hours per year at 2 km.	Visible plume occurrence would be less frequent than that of once-through towers (180 hours per year within 2 kilometers of the tower).	TC
NOISE	No impacts.	Construction would cause some temporary increases in noise in the project area.	Same as for once-through tower.	
		Operation noise beyond about 152 m from the tower would be negligible.	Operation noise beyond about 152 m from the tower would average less than 70 decibels. Sound would consist of fan noise and falling water.	TC
ARCHAEOLOGICAL AND HISTORIC SITES	No impacts.	No impacts.	No impacts.	
RADIOCESIUM TRANSPORT	About 16.2 Ci of radiocesium were released from the K-Reactor area through 1980. Creek sediments at the Pen Branch delta exhibit average cesium-137 concentrations of 4.7 picocuries per gram.	The operation of this alternative would not result in any significant changes in remobilization of radionuclides since flow in Pen Branch would remain essentially unchanged.	The operation of this alternative would reduce flows in Pen Branch resulting in a calculated decrease in the cesium released to the Savannah River of about 0.12 Ci per year.	BC-22
RADIOLOGICAL RELEASES AND DOSES	Cumulative maximum individual effective whole-body dose would continue at about 3.3 millirem per year. Collective effective whole-	Amount of radioactivity released would not change; however, pathway would be affected. Annually, about 50 additional Ci of	Annually, about 425 additional Ci of tritium would be released to atmospheric pathway and 425 less Ci of tritium would be released to liquid	

Table 2-10. Comparison of Cooling Water Alternatives for K-Reactor
(page 5 of 5)

Impacts	No action ^a	Once-through cooling tower (preferred alternative ^b)	Recirculating towers
BC-22	body dose to regional population and downstream water consumers would be about 81 person-rem per year. Population doses are about 0.074 percent of natural background.	tritium would be released to atmospheric pathway and about 50 Ci less of tritium would be released to liquid pathway. This would reduce maximum individual effective whole-body dose by 1.1×10^{-4} millirem per year; collective effective whole-body dose to regional population and downstream water consumers would decrease by 0.028 person-rem per year.	pathway. Change in cesium-137 and tritium release would reduce maximum individual effective whole-body dose by about 0.070 millirem per year; collective effective whole-body dose to regional population and downstream water consumers would decrease by about 0.48 person-rem per year.
BC-22			

- a. No action is defined as the continuation of existing operations of K-Reactor.
- b. The preferred alternative is to construct and operate once-through cooling towers (gravity feed and natural draft). Characterization of environmental effects is based on a natural-draft cooling tower.

Table 2-11. Comparison of Cooling Water Alternatives for C-Reactor
(page 1 of 5)

Impacts	No action ^a	Once-through cooling tower (preferred alternative ^b)	Recirculating towers	
SCHEDULE FOR IMPLEMENTATION	Current	Construction of the system would require about 36 months after a 9-month design period.	Construction of the system would require about 42 months after a 9-month design period.	TC
PRELIMINARY PRESENT-WORTH (MILLION \$)				
- including production loss	\$0	\$44.0	\$89.8	
- excluding production loss	\$0	\$42.4	\$58.0	AD-1 BC-6
ESTIMATED OPERATING COST INCREASE (MILLION \$ PER YEAR)	\$6.2	\$6.4	\$4.4	
SOCIOECONOMICS	No additional work force required.	Peak construction workforce of 200 persons; four additional mechanics required for operation.	Peak construction workforce of 300 persons; six additional mechanics required for operation.	
WATER WITHDRAWAL AND DISCHARGE RATES	About 11.3 cubic meters per second are withdrawn from the Savannah River and discharged into Four Mile Creek.	Withdrawal the same as for no action; discharge to Four Mile Creek would be about 92% of that for no action or 10.5 cubic meters per second.	Withdrawal of river water would be about 14.5% of that for no action or 1.6 cubic meters per second. Discharge to Four Mile Creek would be about 10% of that for no action or about 1 cubic meter per second.	AD-1 BC-12
WATER QUALITY	Dissolved oxygen concentrations in Four Mile Creek are below standards intermittently during summer and total suspended solids are slightly higher than ambient stream levels.	State Class B water classification standards for temperature (32.2°C) and dissolved oxygen concentrations would be met. There would be some reduction in total suspended solids.	State Class B water classification standards for dissolved solids concentrations in discharge would be higher than no action or once-through cooling tower because of cycles of concentration; however, total suspended solids discharged would be greatly reduced.	BB-1 BB-2 BB-3 BC-10

Table 2-11. Comparison of Cooling Water Alternatives for C-Reactor
(page 2 of 5)

	Impacts	No action ^a	Once-through cooling tower (preferred alternative ^b)	Recirculating towers
BB-3	TEMPERATURE AND FLOW EFFECTS	Water temperature in Four Mile Creek would exceed State Class B water classification standards. There would continue to be few aquatic organisms in thermal areas of Four Mile Creek and its delta. Thermal barrier would prevent aquatic movement in Four Mile and Castor Creeks. Fish spawning in creek and delta would remain reduced. There would continue to be potential for cold shock during winter.	State Class B water classification standards for temperature (32.2°C) would be met; Section 316(a) Demonstration study would be performed for exceedances of 2.8°C rise in ambient stream temperatures. Aquatic organisms would become established in present thermal areas. Thermal barrier would be removed. Creek and delta would be opened to fish spawning and foraging. There would be no potential for cold shock because MWAT (EPA, 1977) criteria would be met. Water levels would continue to fluctuate.	State Class B water classification standards for temperature (32.2°C) would be met; Section 316(a) study would also be performed. Mitigation of thermal effects similar to once-through tower would occur, except habitat area for aquatic spawning and foraging would be smaller because of reduced flow, and magnitude of water level fluctuations would be less.
BD-5	ENTRAINMENT/IMPINGEMENT	Water withdrawal would continue to cause entrainment losses of about 13.4×10^6 fish eggs and larvae and the loss of about 2942 fish to impingement annually.	Effects would be about the same as for no action.	Annual entrainment and impingement losses would be reduced to about 2.0×10^6 fish eggs and larvae and 427 fish, respectively.
BC-19 BD-3	HABITAT	Flow and temperature impacts would continue to result in the loss of about 28 acres of wetlands each year.	Wetland losses would decrease; some successional revegetation would occur. About 35 acres of uplands would be affected by construction.	Wetland losses would essentially cease and about 1000 acres of wetlands would successively revegetate; about 60 acres of uplands would be affected by construction.
TC	SOLIDS DEPOSITION	None.	Maximum annual total-solids deposition within about 2 km of the tower would be	Maximum annual total-solids deposition within about 2 km of the tower would be about

Table 2-11. Comparison of Cooling Water Alternatives for C-Reactor
(page 3 of 5)

Impacts	No action ^a	Once-through cooling tower (preferred alternative ^b)	Recirculating towers	
		about 0.5 kilogram per acre per year. Deposition rates are far below levels that cause reduced vegetation productivity.	2.2 kilograms per acre per year. Deposition rates are far below levels that cause reduced vegetation productivity.	TC
ENDANGERED SPECIES	Thermally affected areas of Four Mile Creek and swamp would continue to be too hot for alligators. Low fish densities and high water levels limit forage value for wood stork. No impacts on short-nose sturgeon and red-cockaded woodpecker.	Alligator habitat would be improved by lower water temperatures. Some improvement of wood stork foraging habitat would result from increased fish concentrations although continued high flows would maintain deep water conditions. No impacts on shortnose sturgeon, red-cockaded woodpecker, and bald eagle.	Some alligator habitat would be available; however, lower flows would decrease potential habitat area resulting in less improvement than with once-through tower. Potential for improvement of wood stork habitat would be increased due to lower water levels in the creek and delta. No impacts on shortnose sturgeon, red-cockaded woodpecker, and bald eagle.	TC
AIR QUALITY	No impacts.	Construction would result in temporary small increases in carbon monoxide and hydrocarbons from engine exhaust. Also some transient increases in airborne dust. Maximum annual-mean frequency of reduced ground-level visibility to less than 1000 m would be about 2 hours per year. Maximum ice accumulation on horizontal surfaces would be no more than 1 mm.	Construction impacts would be similar to those for once-through tower. Reduction in ground-level visibility would be about 2 hours per year. Maximum ice accumulation on horizontal surfaces would be no more than 1 mm beyond 0.8 km of the tower. Maximum	TC

Table 2-11. Comparison of Cooling Water Alternatives for C-Reactor
(page 4 of 5)

	Impacts	No action ^a	Once-through cooling tower (preferred alternative ^b)	Recirculating towers
TC				predicted thickness would be 7 mm, occurring within 0.4 km of the tower with a total frequency of 88 hours per winter season.
			Maximum occurrence of visible plumes would be about 180 hours per year within 0.4 km of the tower and 30 hours per year at 2 km.	Visible plume occurrence would be 100 hours per year within 2 km of the towers.
BC-22	NOISE	No impacts.	Construction would cause some temporary increases in noise in the project area.	Same as for once-through tower.
			Operation noise beyond about 152 m from the tower would be negligible.	Operation noise beyond about 152 m from the tower would average less than 70 decibels. Sound would consist of fan noise and falling water.
	ARCHAEOLOGICAL AND HISTORIC SITES	No impacts.	One small nonsignificant prehistoric lithic and ceramic scatter near Four Mile Creek would be disturbed.	Same site would be disturbed as with once-through tower.
	RADIOCESIUM TRANSPORT	About 21.9 Ci of radiocesium were released from the C-Reactor area through 1980. Creek sediments at SRP Road A-7 exhibit average cesium-137 concentrations of 37.5 picocuries per gram.	The operation of this alternative would not result in any significant changes in remobilization of radionuclides since flow in Four Mile Creek would remain essentially unchanged.	The operation of this alternative would reduce flows in Four Mile Creek resulting in a calculated decrease in cesium released to the Savannah River of about 0.21 Ci per year.
	RADIOLOGICAL RELEASES AND DOSES	Cumulative maximum individual effective whole-body dose would continue at about	Amount of radioactivity released would not change; however, pathway would be	Annually, about 425 additional Ci of tritium would be released to atmospheric pathway

Table 2-11. Comparison of Cooling Water Alternatives for C-Reactor
(page 5 of 5)

Impacts	No action ^a	Once-through cooling tower (preferred alternative ^b)	Recirculating towers
	3.3 millirem per year. Collective effective whole-body dose to the regional population and downstream water consumers would be about 81 person-rem per year. Population doses are about 0.074 percent of natural background.	affected. Annually, about 50 additional Ci of tritium would be released to atmospheric pathway and about 50 Ci less of tritium would be released to liquid pathway. This would reduce maximum individual effective whole-body dose by 1.1×10^{-4} millirem per year and collective effective whole-body dose to regional population; downstream water consumers would decrease by 0.028 person-rem per year.	and 425 less Ci of tritium would be released to liquid pathway. Change in cesium-137 and tritium releases would reduce maximum individual effective whole-body dose by about 0.12 millirem per year; collective effective whole-body dose to regional population and downstream water consumers would decrease by about 0.66 person-rem per year.

BC-22

- No action is defined as the continuation of existing operations of C-Reactor.
- The preferred alternative is to construct and operate once-through cooling towers (gravity feed and natural draft). Characterization of environmental effects is based on a natural-draft cooling tower.

improved because of lower water temperatures and intermittent higher flows. The direct-discharge alternative would remove the D-Area powerhouse thermal discharge from Beaver Dam Creek and would reduce the creek flow to near-ambient levels. This alternative would result in a significant reduction in the available aquatic habitat in the creek, and would adversely affect alligators that now use these areas. Heated effluent discharged directly into the Savannah River would not adversely affect the River's aquatic habitat because a zone of passage would be maintained.

The increased-flow alternative would affect an estimated 4 acres of wetlands and 4 acres of uplands due to intermittent flooding when the system is operating. Construction of the pipeline for the direct-discharge alternative would adversely affect about 1 acre of wetlands and 5 acres of uplands.

BD-5 | Entrainment and impingement impacts would remain at present levels for the direct-discharge alternative. However, increased flow with mixing would result in annual entrainment losses of about 6.0×10^4 fish eggs and larval and impingement losses of about 113 fish.

Habitat for the American alligator and the wood stork would not be affected appreciably by the increased-flow alternative; however, during its operation, the intermittent increases in water level could decrease the area of foraging habitat for the wood stork. Implementation of the direct-discharge system would degrade much of the existing alligator and wood stork habitat in Beaver Dam Creek due to the significant decrease in flow and elimination of slightly warmer winter temperatures.

No radiological impacts will occur from the implementation of either alternative for the D-Area powerhouse.

Table 2-12 provides a summary comparison of the alternatives for D-Area.

Table 2-12. Comparison of Cooling Water Alternatives for D-Area
(page 1 of 3)

Impacts	No action ^a	Increased flow with mixing (preferred alternative)	Direct discharge to Savannah River
SCHEDULE FOR IMPLEMENTATION	Current	Current	Construction of this alternative would require about 22 months.
PRELIMINARY PRESENT-WORTH (MILLION \$)	\$0	\$0	\$14
ESTIMATED OPER- ATING COST INCREASE (MIL- LION \$ PER YEAR)	\$0	\$0.03	\$0.05
SOCIOECONOMICS	No additional workforce required.	No additional workforce required.	Peak construction workforce of 40 persons.
WATER WITHDRAWAL AND DISCHARGE RATES	About 2.6 cubic meters per second would continue to be withdrawn from the Savannah River and discharged to Beaver Dam Creek.	Withdrawal and discharge rates would be the same as for no action except when withdrawal and discharge rates each could be as high as 4.5 cubic meters per second to meet the 32.2°C State Class B water classi- fication standard.	Withdrawal and discharge rates would be the same as for no action; however, thermal discharge would be directly to the Savannah River. All powerhouse thermal discharges would be removed from Beaver Dam Creek.
TEMPERATURE AND FLOW EFFECTS	Water temper- atures in Beaver Dam Creek would continue to exceed the 32.2°C State Class B water classi- fication standard during periods from May through September; water temperatures would also exceed the maximum ambient stream temperature rise standard of 2.8°C. Concen- trations of suspended solids would remain slightly higher than in ambient streams.	Water temperatures in the stream would meet the 32.2°C State Class B water classi- fication standard; a Section 316(a) Demonstration study will be performed for exceedances of 2.8°C rise in ambient stream temperature. Slight increases in suspended solids concen- trations would occur during periods of increased flow. Aquatic fauna would become established in	In Beaver Dam Creek, water temperatures would be at ambient levels year-round. In the Savannah River, water temper- atures beyond a mixing zone at the discharge point would meet the State Class B water quality classi- fication standard of 32.2°C. Low water levels in Beaver Dam Creek would greatly reduce existing aquatic habitat; however, the absence of thermal stress would allow full use of this habitat by aquatic organisms. There would be no

Table 2-12. Comparison of Cooling Water Alternatives for D-Area
(page 2 of 3)

Impacts	No action ^a	Increased flow with mixing (preferred alternative)	Direct discharge to Savannah River
	There would continue to be reduced numbers of aquatic organisms and spawning in the thermally affected areas of Beaver Dam Creek during the warmer months. A thermal barrier would continue to restrict movement of fish in the creek.	present thermally affected areas of Beaver Dam Creek. Habitat area would increase during periods of increased flow. There would be no thermal barrier in the creek.	thermal barrier in the creek. Fish spawning would be limited because of reduced habitat. An adequate zone of passage would be present in the river.
ENTRAINMENT/ IMPINGEMENT	Water withdrawal would continue to cause entrainment losses of about 2.0×10^6 fish eggs and larvae and the loss of about 1718 fish due to impingement annually.	Increased water withdrawal over that for no action would increase entrainment losses by about 2.4×10^4 fish eggs and larvae and the loss of an additional 113 fish due to impingement annually.	Effects would be about the same as for no action.
HABITAT	No impacts.	Operation would result in an estimated loss of about 4 acres of wetlands and about 4 acres of uplands.	Construction would result in an estimated loss of about 1 acre of wetlands and 5 acres of uplands.
AIR QUALITY	No impacts.	No impacts.	No impacts.
ENDANGERED SPECIES	Existing thermal areas of Beaver Dam Creek would continue to support a large alligator population. The adjacent swamp area would continue to be used by wood storks for foraging. No impacts on other endangered species.	No changes in existing alligator habitat. Some decrease in wood stork foraging habitat during increased flow periods. No impacts on other endangered species.	Loss of most of alligator habitat due to decreased temperatures and lowered water levels in Beaver Dam Creek. Loss of much of wood stork foraging habitat due to lowered water levels in Beaver Dam Creek. No impacts on other endangered species.

BD-5

Table 2-12. Comparison of Cooling Water Alternatives for D-Area
(page 3 of 3)

Impacts	No action ^a	Increased flow with mixing (preferred alternative)	Direct discharge to Savannah River
ARCHAEOLOGICAL AND HISTORICAL SITES	No impacts.	One site will be recommended for eligibility for nomination to the <u>National Register of Historic Places</u> . A "no effect" determination was obtained from the South Carolina SHPO with concurrence from the Advisory Council on Historic Preservation.	Survey of pipeline area revealed no historic sites.
RADIOLOGICAL RELEASES	No impacts.	No impacts.	No impacts.

AT-1
AT-2
AZ-1

- a. No action is defined as the continuation of existing operations of the D-Area coal-fired powerhouse.

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CHAPTER 3

AFFECTED ENVIRONMENT

This chapter describes the environment of the Savannah River Plant (SRP) and the nearby region that would be affected by the cooling water alternatives associated with K- and C-Reactors and the D-Area powerhouse; it also describes the three affected onsite streams.

3.1 SAVANNAH RIVER PLANT SITE AND REGION

3.1.1 GEOGRAPHY

The Savannah River Plant is located in southwestern South Carolina. The SRP occupies an almost circular area of about 780 square kilometers (192,741 acres), bounded on its southwestern side by the Savannah River, which is also the border between the States of South Carolina and Georgia. Portions of Barnwell, Aiken, and Allendale Counties, South Carolina, lie inside the SRP boundary. The major population centers closest to the SRP site are Augusta in Georgia, and Aiken, North Augusta, and Barnwell in South Carolina. Figure 3-1 shows the location of the SRP site in relation to surrounding population centers within a 240-kilometer radius.

TE

The SRP facilities include five nuclear production reactors (three currently operating and two in standby condition), two chemical separations areas, a fuel and target fabrication facility, and various supporting facilities (Figure 3-2).

TC

The locations of the various Plant areas with reference to the five major stream systems that drain the site are shown in Figure 3-2. Most of the Plant areas drain toward the Savannah River, which ranges from 27 to 104 meters above sea level. C-Reactor is located near the middle of the SRP site. K-Reactor is about 5 kilometers southeast of C-Reactor. L- and P-Reactors are about 5 and 10 kilometers east of K-Reactor, respectively. R-Reactor is about 12 kilometers northeast of K-Reactor. The D-Area powerhouse is about 10 kilometers southwest of C-Reactor.

Almost all the SRP site is drained by tributaries of the Savannah River. Each tributary is fed by several small streams. One small stream in the northeastern sector of the site drains to the Salkehatchie River rather than the Savannah River.

The southwestern border of the Plant is the Savannah River Swamp System (SRSS). About 10,000 acres of the Savannah River swamp forest lie on the Plant from Upper Three Runs Creek to Steel Creek. The SRP swamp area borders the Savannah River for approximately 16 kilometers and averages about 2.4 kilometers in width (Figure 3-2).

TE

A small embankment or natural levee has been built up along the north side of the river by sediments deposited during periods of flooding. Three breaches in the levee allow water from Steel Creek, Four Mile Creek, and Beaver Dam Creek to flow to the river. The combined discharges of Steel Creek and Pen

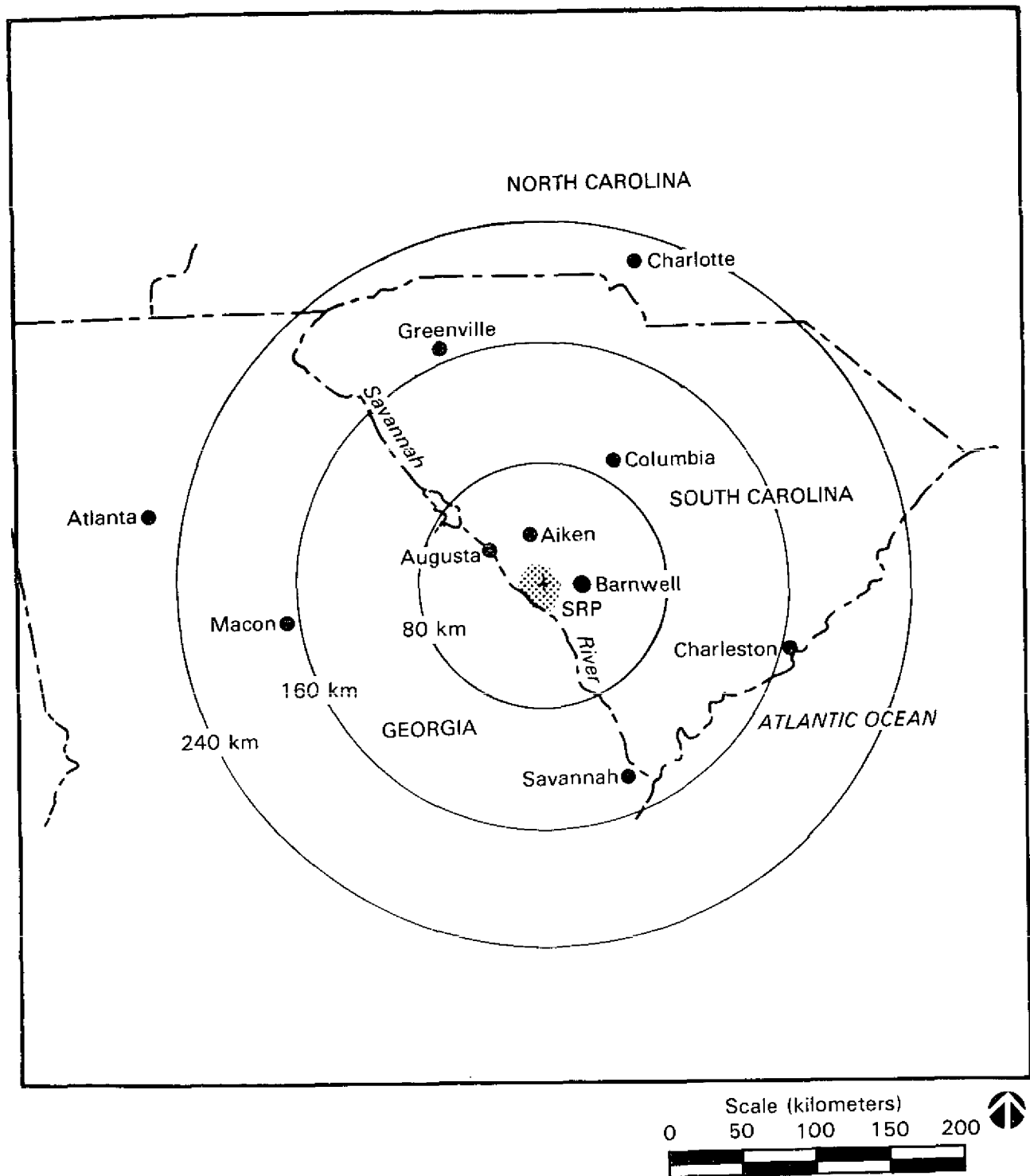


Figure 3-1. SRP Location in Relation to Surrounding Population Centers

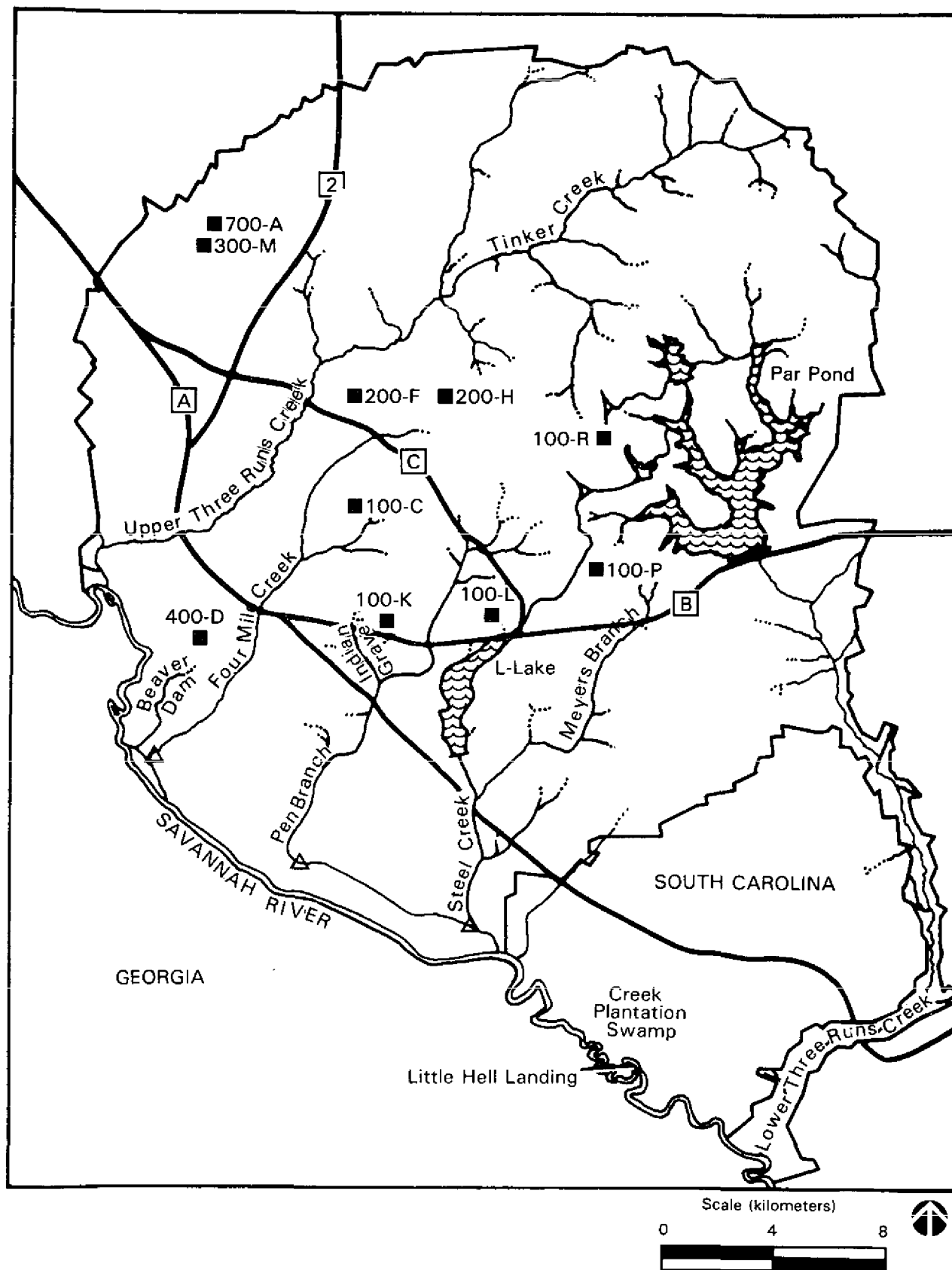


Figure 3-2. Savannah River Plant Site Map

Branch enter the river near the southeastern corner of the Plant. On the landward side of the levee, the ground elevation decreases to form the swamp system, which contains stands of cypress-tupelo forest, bottomland hardwoods, and some open marsh areas.

During periods of high river level, river water overflows the levee and stream mouths and floods the entire swamp area, leaving only isolated islands. The overflows occur when river elevations exceed 27 meters above mean sea level (MSL) as measured at the SRP boat dock. During flooding, the water from these streams flows through the swamp parallel to the river and enters the river southeast of the mouth of Steel Creek at Little Hell Landing after crossing an offsite swamp.

3.1.2 SOCIOECONOMIC AND COMMUNITY CHARACTERISTICS

A comprehensive description of socioeconomic and community characteristics for the area around the Savannah River Plant was presented in the report Socioeconomic Baseline Characterization for the Savannah River Plant Area, 1981 (ORNL, 1981). Information contained in the 1981 report was subsequently updated in the report Socioeconomic Data Base Report for Savannah River Plant (DOE, 1984a); additional information on the topics presented in this section can be found in the updated report.

3.1.2.1 Study Area

The permanent operating and construction force at the Savannah River Plant has averaged 7500, ranging from a low of 6000 in the 1960s to the current 14,957 (June, 1987). In 1980, approximately 97 percent of SRP employees resided in a 13-county area surrounding the Savannah River Plant (Table 3-1). Of these 13 counties, 9 are in South Carolina and 4 are in Georgia. The greatest percentage of employees now reside in the six-county area of Aiken, Allendale, Bamberg, and Barnwell Counties in South Carolina, and Columbia and Richmond Counties in Georgia (Figure 3-3). Together, these six counties house approximately 89 percent of the total SRP workforce. These six counties were chosen as the study area for the assessment of potential socioeconomic and community effects of the proposed cooling water alternatives because the percentage of employees residing in these counties has remained essentially the same since the early 1960s.

3.1.2.2 Demography

Table 3-2 lists the 1980 populations in the study area for counties and places of more than 1000 persons. The largest cities in the study area are Augusta in Georgia, and Aiken, North Augusta, and Barnwell in South Carolina. Of the 31 incorporated communities in the study area, 16 have populations under 1000 persons, and 11 have populations between 1000 and 5000 persons. Aiken, Columbia, and Richmond Counties, which comprise the Augusta Standard Metropolitan Statistical Area (SMSA), had a total population of about 327,400 in 1980; however, most of this population resides outside cities or towns. About two-thirds of the total six-county population resides in rural or unincorporated areas.

Over the last three decades, the rate of population growth has varied from county to county. From 1950 to 1980, the counties comprising the Augusta SMSA

Table 3-1. Distribution of June 1980 SRP
Employees by Place of Residence

Location of residence	Percent of SRP labor force
South Carolina	80.0
Aiken County	58.8
Allendale County	1.8
Bamberg County	2.0
Barnwell County	8.8
Edgefield County	1.1
Hampton County	1.2
Lexington County	1.6
Orangeburg County	1.7
Saluda County	1.0
Other counties	2.0
Georgia	20.0
Columbia County	3.1
Richmond County	14.8
Burke County	0.3
Screven County	0.8
Other counties	0.9
Other states	0.1
Total	100.0

Source: DOE, 1984b.

TC

experienced a positive growth rate; the combined average annual rate was about 3 percent. The most significant population increases occurred in Columbia County, which experienced an average growth rate between 1960 and 1980 of about 10 percent per year. The rural counties - Allendale, Bamberg, and Barnwell - experienced population declines between 1950 and 1970; reversals of this decline occurred between 1970 and 1980 when population increases for these counties ranged from 9 to 16 percent. The population growth rate experienced in the study area during the last two decades was about equal to that experienced in the southern United States and slightly less than the growth rate experienced in the South Atlantic Region (Bureau of the Census, 1983).

In 1980 the estimated population in the 80-kilometer area around the Savannah River Plant was approximately 563,300 persons. The year 2000 population in this area is estimated at 852,000 persons. This estimate was calculated using the 1970-to-1980 growth rate of each county in the 80-kilometer area, assuming these growth rates would continue in the future. For counties that experienced a negative population growth rate between 1970 and 1980, the calculation assumed that no continued population decline would occur.

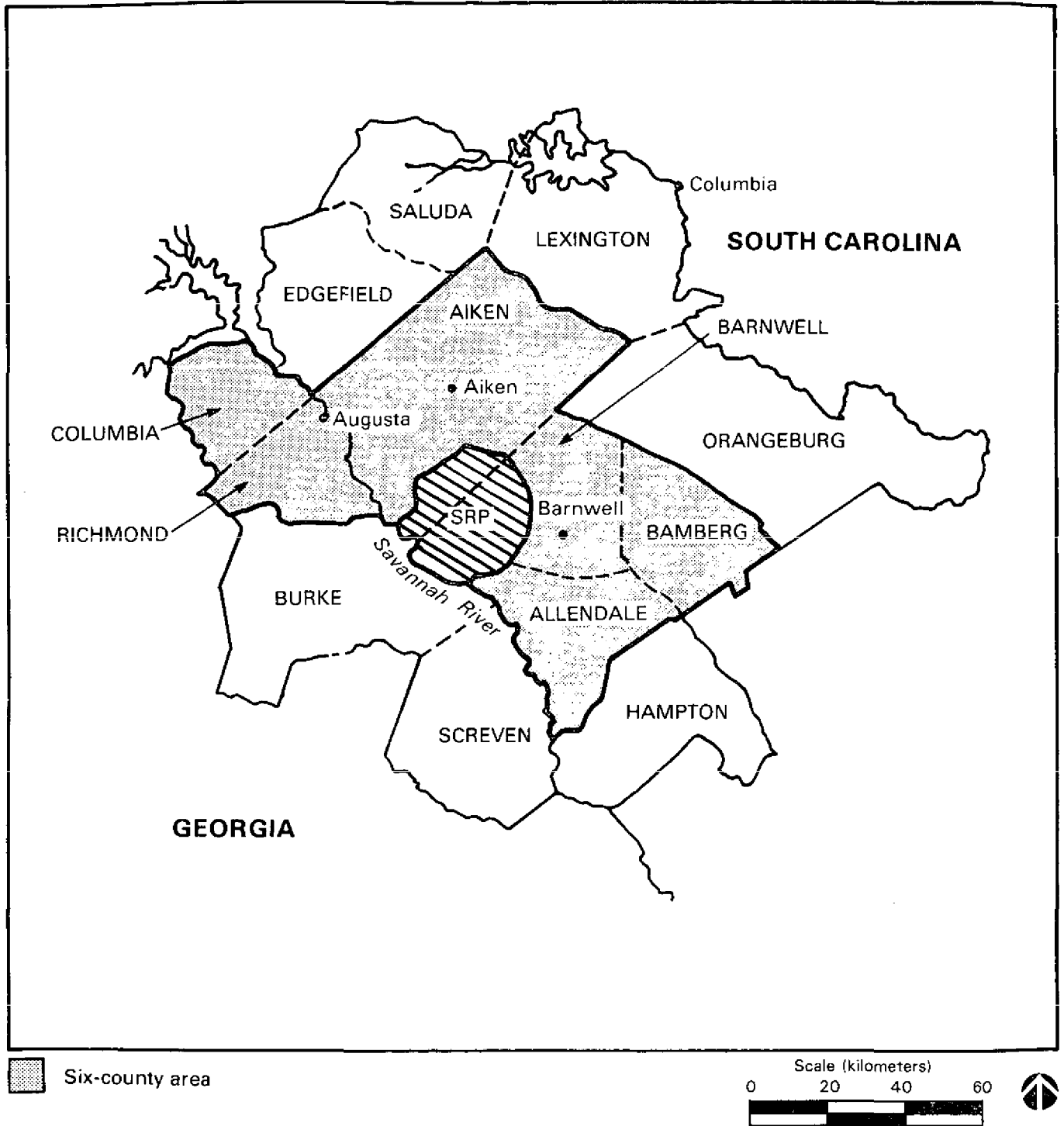


Figure 3-3. Counties in SRP Area

Table 3-2. 1980 Population for Counties and Places
of 1000 Persons or Greater^a

Location	1980 population
Aiken County, South Carolina	105,625
City of Aiken	14,978
Town of Jackson	1,771
City of North Augusta	13,593
City of New Ellenton	2,628
Allendale County, South Carolina	10,700
Town of Allendale	4,400
Town of Fairfax	2,154
Bamberg County, South Carolina	18,118
Town of Bamberg	3,672
City of Denmark	4,434
Barnwell County, South Carolina	19,868
City of Barnwell	5,572
Town of Blackville	2,840
Town of Williston	3,173
Columbia County, Georgia	40,118
City of Grovetown	3,384
City of Harlem	1,485
Richmond County, Georgia	181,629
City of Augusta	47,532
Town of Hephzibah	1,452
Study area total	376,058

a. Adapted from the Bureau of the Census (1982a,b).

3.1.2.3 Land Use

In the six-county study area, less than 8 percent of the existing land use is devoted to urban and developed uses. Most land uses of these types are in and around the Cities of Augusta and Aiken. Agriculture accounts for about 21 percent of total land use; forests, wetlands, water bodies, and unclassified lands that are predominantly rural account for about 70 percent of total land use.

All the counties in the study area have a land-use plan, and Columbia and Richmond Counties have zoning ordinances. The projected future land uses of the study area are very similar to the existing land-use patterns. Developed urban land is projected to increase by 2 percent in the next 20 years. The

largest percentage of this growth is expected to occur in Aiken and Columbia Counties, as a result of the expansion of the Augusta metropolitan area.

Agricultural land throughout the study area is undergoing a transition from smaller operations to larger consolidated farms. This is especially true in the rural areas of Allendale, Bamberg, and Barnwell Counties.

3.1.2.4 Public Services and Facilities

There are nine public school systems in the study area. County-wide school districts are located in each county except Bamberg, which has two districts, and Barnwell, which has three. An estimated total of 3642 new students could have been accommodated in the study area school districts in 1982.

Of the 120 public water systems in the study area, 30 county and municipal systems serve about 75 percent of the population. All but four of the municipal and county water systems - the Cities of Aiken, Augusta, and North Augusta, and Columbia County - obtain their water from deep wells. Aiken obtains some of its water from Shaws Creek and Shiloh Springs, while Columbia County and the Cities of Augusta and North Augusta obtain water from the Savannah River. For those municipal and county water systems that use groundwater as their supply, restrictions in system capabilities are due primarily to storage and treatment capacity rather than availability of groundwater.

Most municipal and county wastewater-treatment systems have the capacity to treat additional sewage. Selected rural municipalities in Allendale, Bamberg, and Columbia Counties and the City of Augusta in Richmond County have experienced problems in treatment-plant capacities. Programs to upgrade facilities are under way or planned in most of these areas.

3.1.2.5 Housing

Since 1970, the largest increases in the number of housing units have occurred in Columbia, Richmond, and Aiken Counties. Columbia County has grown the fastest, more than doubling its number of housing units. Between 1970 and 1980, Aiken and Richmond Counties each experienced about a 36-percent increase in the number of housing units. In Aiken County, one-fourth of this increase resulted from the high growth rate in the number of mobile homes.

The vacancy rate for owner-occupied housing units for the six-county area in 1980 was 2.3 percent. Individual county rates ranged from 3.6 percent in Columbia County to 0.8 percent in Barnwell County. Vacancy rates for rental units in 1980 ranged from 14.8 percent in Columbia County to 7.1 percent in Bamberg County; the average for the study area was 10.5 percent.

3.1.2.6 Economy

The results of the 1980 Census of Population indicate that between 1970 and 1980 there was a 35-percent increase in total employment, from 75,732 to 102,326 employees, in establishments with payrolls in the six-county area. Service sector employment increased at these establishments by 65 percent, mirroring a national trend toward a service-based economy. Employment in

manufacturing increased by 27 percent, adding more than 9000 employees. Most of the overall expansion in the number of employment positions occurred in Richmond and Aiken Counties.

About 31 percent of the workforce in the six-county area in 1980 was employed in the service sector, and 27 percent in the manufacturing sector. Retail trade was the third largest category, accounting for 15 percent of the workforce. The remaining 27 percent of the workforce was dispersed among the seven additional categories of employment reported by the Census. In 1980, fewer than 2 percent of workers in the study area were employed in the category of agriculture, forestry, and fishing, while nearly 4 percent were employed in that category in 1970.

3.1.3 HISTORIC AND ARCHAEOLOGICAL RESOURCES

In 1985, 69 sites in the study area were listed in the National Register of Historic Places (see Appendix E). Richmond County had the largest number of sites (27), most of which are in the City of Augusta. Approximately 25 more National Register sites are in Aiken and Allendale Counties.

TC

TC

In past years, the South Carolina Institute of Archaeology and Anthropology has conducted various archaeological surveys on the Savannah River Plant through the Savannah River Plant Archaeological Resource Program. An intensive archaeological and historic survey was conducted in 1984 in the Pen Branch and Four Mile Creek watersheds (Figure 3-4). As discussed in Appendix E, 65 sites were located, about two-thirds of which were not considered significant due to the lack of site integrity and limited research potential. Consultations with the State Historic Preservation Officer have determined that none of the potentially significant sites possess the necessary characteristics for nomination for inclusion in the National Register of Historic Places (see Appendix E). Intensive archaeological and historic resources surveys of the Beaver Dam Creek floodplain area and the area west of the creek in D-Area were conducted during October and November of 1985. Only one site, 38BR450, was located in the survey areas. As discussed in Appendix E, site 38BR450 is considered a significant archaeological resource and has been recommended for eligibility for nomination to the National Register of Historic Places.

AT-1

AT-2

AZ-1

3.1.4 GEOLOGY

3.1.4.1 Geologic Setting

The Savannah River Plant is located in the Aiken Plateau physiographic division of the Upper Atlantic Coastal Plain of South Carolina (Cooke, 1936). Figure 3-5 shows a generalized northwest-to-southeast geologic profile across the Savannah River Plant. The Aiken Plateau at the Plant is characterized by interfluvial areas with narrow, steep-sided valleys. Because of the Plant's proximity to the Piedmont region, it has somewhat more relief than the near coastal areas; onsite elevations range from 27 to 104 meters above mean sea level.

The center of the Plant is about 40 kilometers southeast of the Fall Line (Davis, 1902) that separates the Atlantic Coastal Plain physiographic province from the Piedmont physiographic province (Figure 3-5). Crystalline rocks of

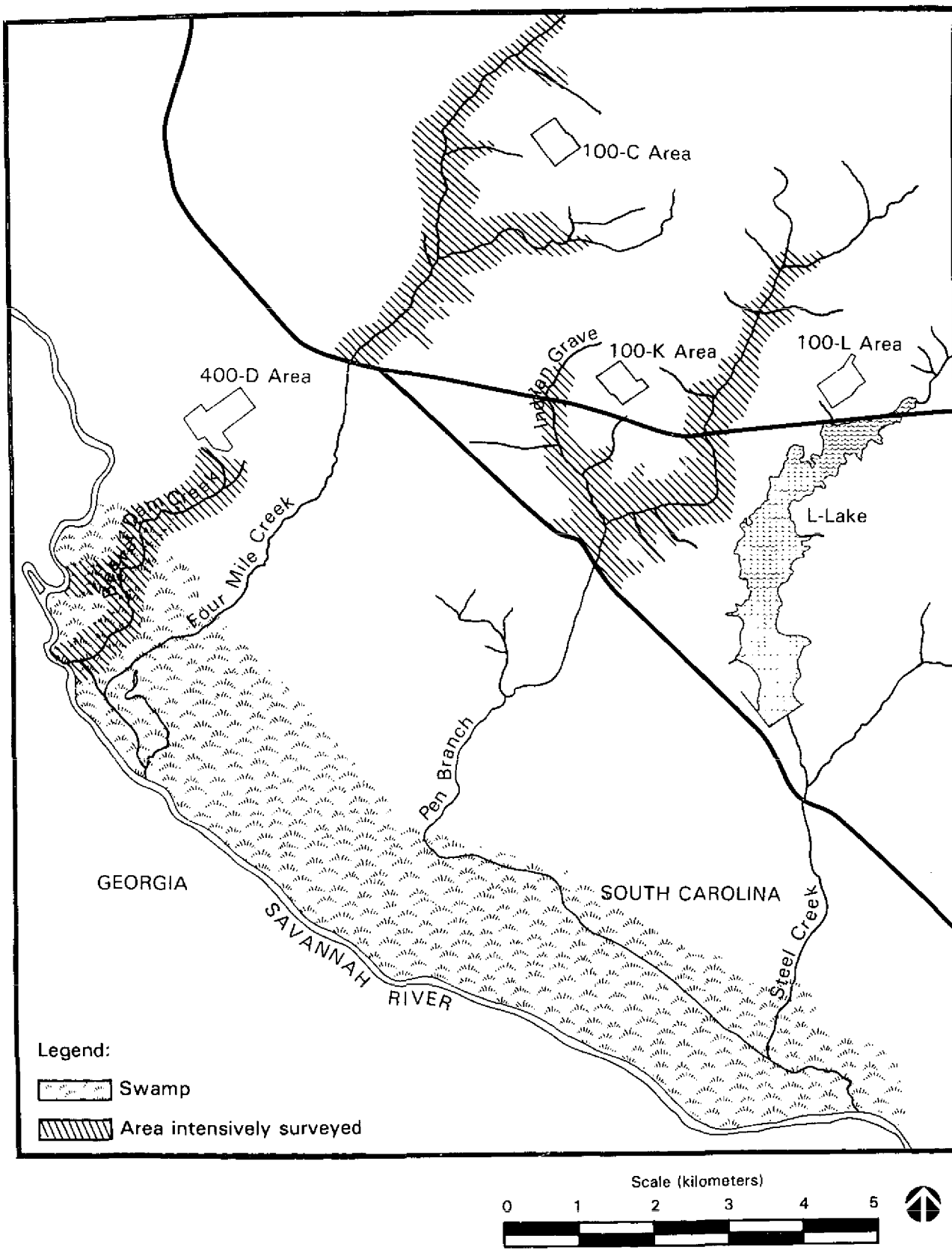
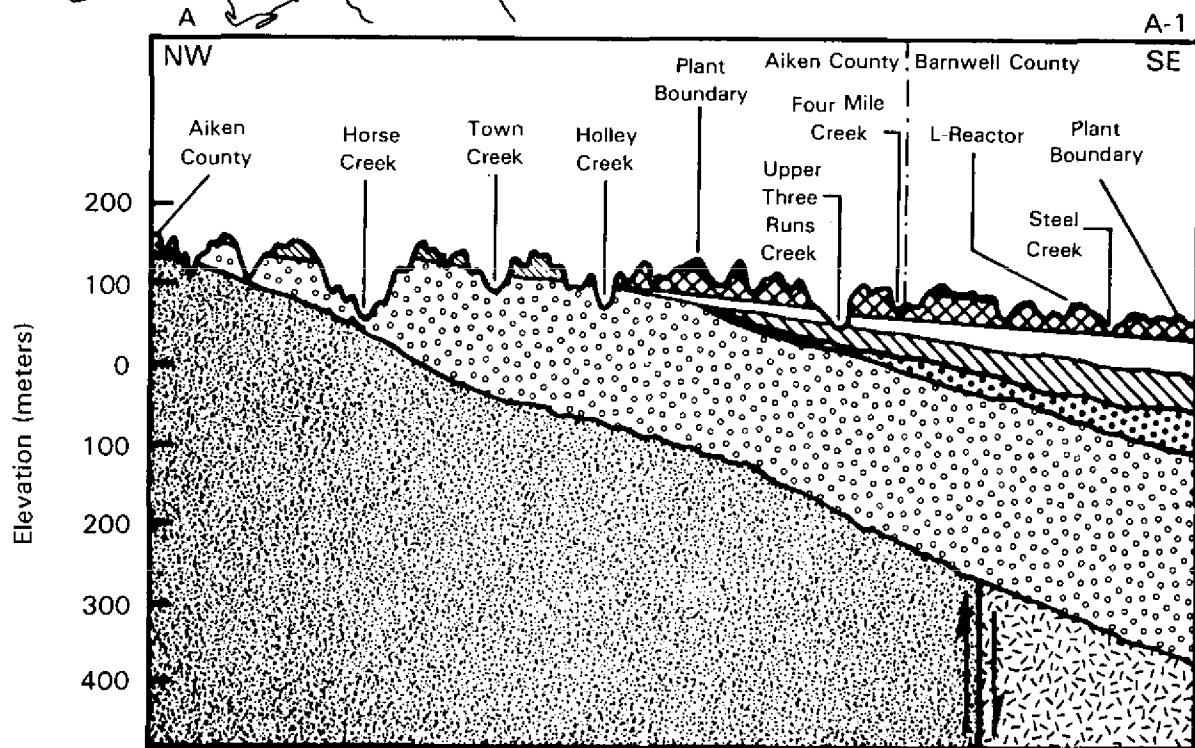
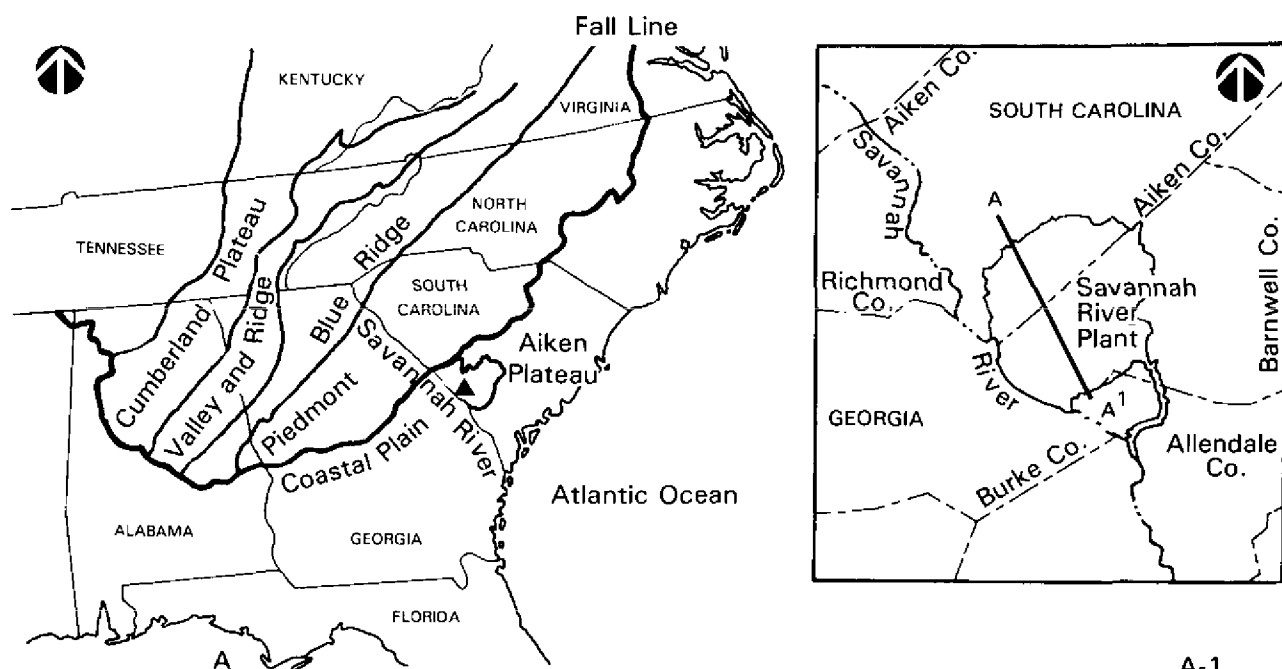


Figure 3-4. General Map of Archaeological Survey Area



Source: Adapted from DOE, 1984b; Modified from Siple, 1967

Legend:

- | | | |
|-----------------------------------|--------------------------------|--------------|
| ■ Hawthorn | □ McBean | ▤ Ellenton |
| ▨ Barnwell | ▧ Congaree | ▥ Tuscaloosa |
| ▩ Tertiary rocks undifferentiated | ▦ Crystalline metamorphic rock | ▧ Dunbarton |

Figure 3-5. Generalized NW to SE Geologic Profile Across the Savannah River Plant

Precambrian and Paleozoic age underlie a major portion of the gently seaward-dipping coastal plain sediments of Cretaceous and younger age. Sediment-filled basins of Triassic and Jurassic age (exact age is uncertain) occur within the crystalline basement throughout the coastal plain of Georgia and the Carolinas (DOE, 1984b). One of these, the Dunbarton Triassic Basin, underlies parts of the Plant (Marine and Siple, 1974).

TC | 3.1.4.2 Stratigraphy*

TE | Coastal Plain sediments in South Carolina range in age from Cretaceous to
TC | Quaternary; they form a seaward-dipping and thickening wedge of mostly uncon-
solidated sediments. Near the center of the Plant at H-Area, these sediments
are approximately 280 meters thick (Siple, 1967). The base of the sedimentary
wedge rests on a Precambrian and Paleozoic crystalline basement, which is
similar to the metamorphic and igneous rocks of the Piedmont, and on the silt-
stone and claystone conglomerates of the down-faulted Dunbarton Triassic Basin
(Figure 3-5). Immediately overlying the basement are the Middendorf-Black
Creek (Tuscaloosa) Formations (175 meters thick), which are of Upper
Cretaceous age and are composed of waterbearing sands and gravels separated by
prominent clay units. Overlying the Middendorf/Black Creek is the Ellenton
Formation, which is about 18 meters thick and consists of sands and clays
interbedded with coarse sands and gravel (Siple, 1967). Four of the forma-
tions shown in Figure 3-5 - the Congaree, McBean, Barnwell, and Hawthorn -
comprise the Tertiary (Eocene and Miocene) sedimentary section, which is about
85 meters thick and consists predominantly of clays, sands, clayey sands, and
sandy marls. The near-surface sands of the Barnwell and Hawthorn Formations
are generally loosely consolidated; they often contain thin, sediment-filled
fissures (clastic dikes) (DOE, 1984b).

Quaternary alluvium is found at the surface in floodplain areas and as terrace
deposits. Soils at the Plant are generally uniform and rather shallow, about
1 meter deep. They are characterized by bleached Barnwell-Hawthorn sediments,
which result in a light-tan sandy loam.

3.1.4.3 Geologic Structures

The down-faulted Dunbarton Triassic Basin underlies the southeastern portion
of the Savannah River Plant and contains several interbasinal faults. How-
ever, the sediments overlying these faults show no evidence of basin-induced
movement since their deposition during the Cretaceous Period (Siple, 1967;

TC | *The accepted names for stratigraphic units are continually evolving as
additional information on the age of the units and their correlation with
similar units in other areas has surfaced. This is reflected in the different
names used by authors to identify subsurface units. The stratigraphic
nomenclature used in this document is the same as the usage of the various
authors whose works have been referenced. Therefore, different portions of
the text might use different names for the same geologic units. Similarly,
the same name might be used for geologic units or portions of units that are
otherwise different. Figure 3-6 shows the correlation of the units used by
the various authors. The terminology used in this document is largely that of
Siple (1967).

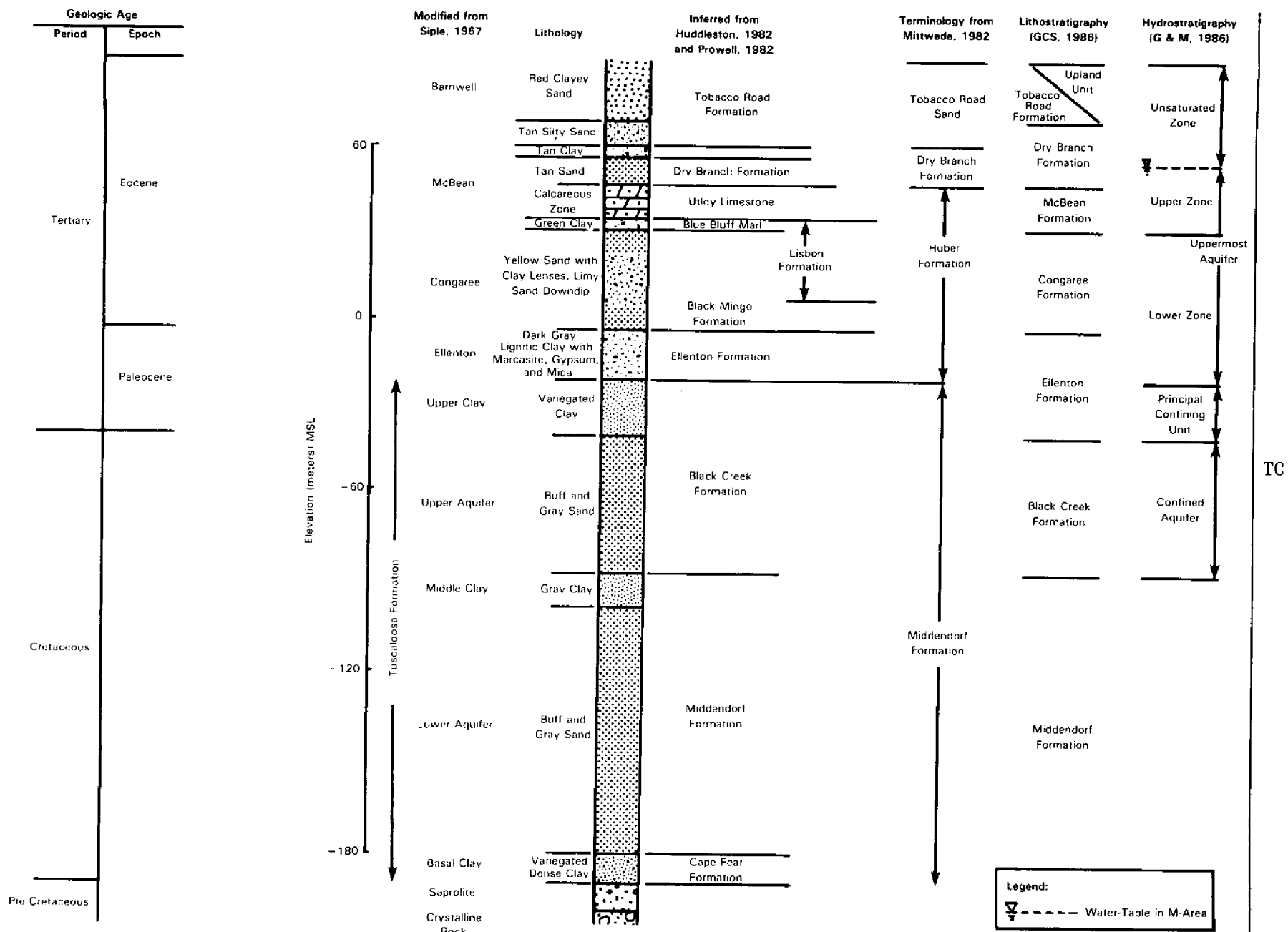


Figure 3-6. Tentative Correlation of Stratigraphic Terminology of Southwestern South Carolina Coastal Plain

Marine and Siple, 1974). Other Triassic-Jurassic basins have been identified in the Coastal Plain tectonic province of South Carolina and Georgia; these features can be associated with the South Georgia Rift (Marine and Siple, 1974; Popenoe and Zietz, 1977; Daniels, Popenoe, and Zietz, 1983). The Piedmont, Blue Ridge, and Valley and Ridge tectonic provinces, which are associated with Appalachian Mountain building, are northwest of the Fall Line (Figure 3-5). Several fault systems occur in and adjacent to the Piedmont and the Valley and Ridge tectonic provinces of the Appalachian system; the closest of these is the Belair Fault Zone, about 40 kilometers from the Plant, which is not capable of generating major earthquakes (Case, 1977).

Surface mapping, subsurface boring, and geophysical investigations at the Plant have not detected any faulting of the sedimentary strata or any other geologic hazards that would affect SRP facilities (DOE, 1984b).

3.1.4.4 Seismicity

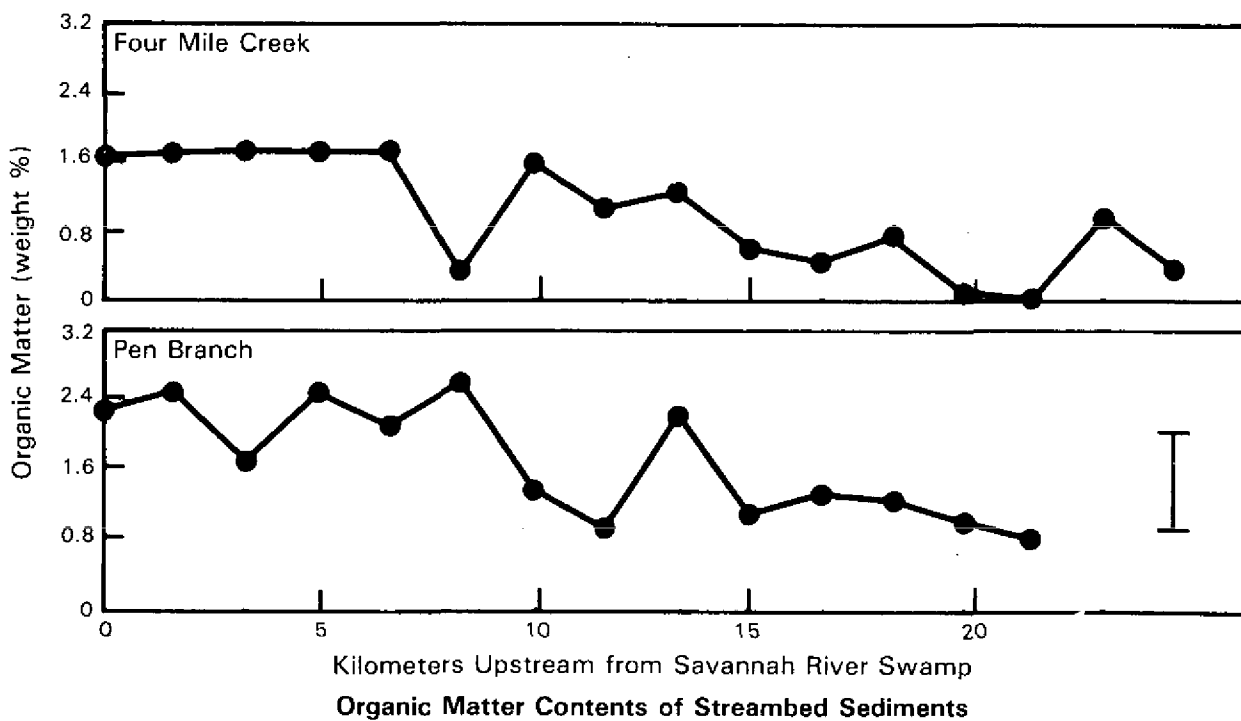
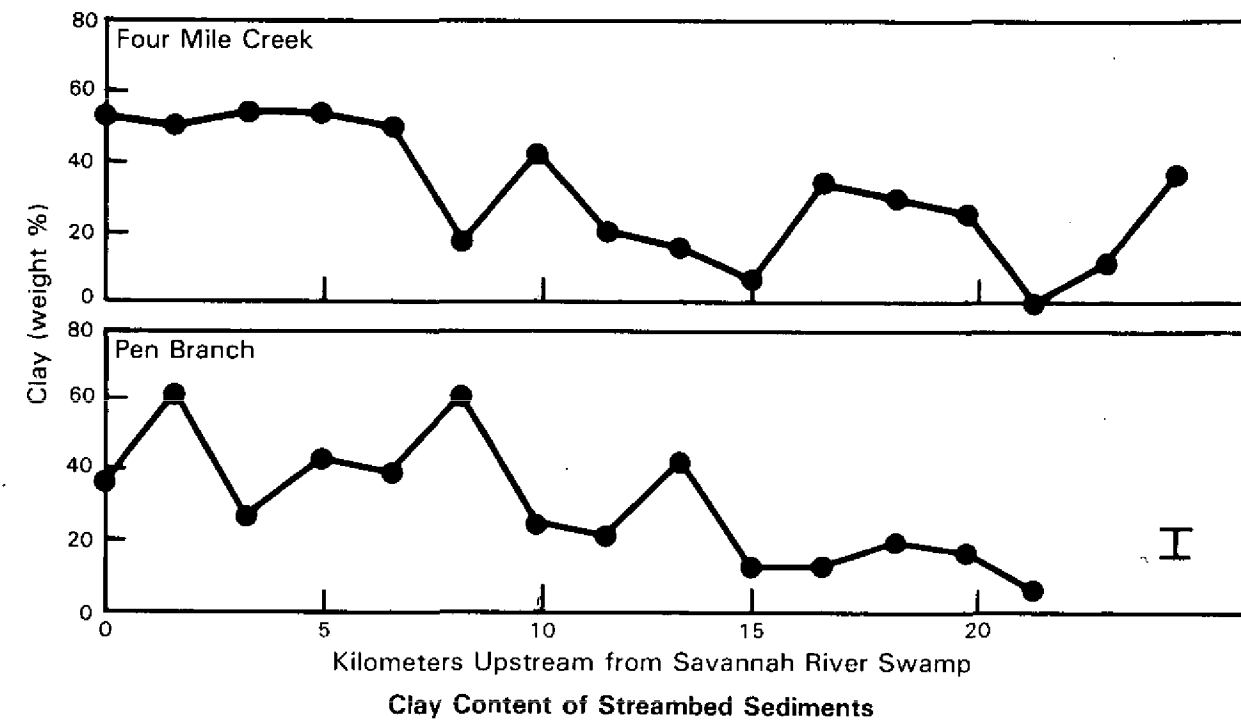
Two major earthquakes have occurred within 300 kilometers of the Savannah River Plant: the Charleston earthquake of 1886, which had an epicentral modified Mercalli intensity (MMI) of X, and was located about 145 kilometers away; and the Union County, South Carolina, earthquake of 1913, which had an epicentral shaking of MMI VII to VIII, and was located approximately 160 kilometers away (Langley and Marter, 1973). An estimated peak horizontal shaking of 8 percent of gravity (0.08g) was calculated for the site during the 1886 earthquake (Du Pont, 1982a). Site intensities and accelerations for other significant earthquakes have been published by DOE (1982, p. G-7). No reservoir induced seismicity is associated with Par Pond (see Figure 3-2).

On June 8, 1985, a minor earthquake of local magnitude 2.6 (maximum intensity: MM III), and focal depth of 0.96 kilometer occurred at the Plant near Aiken, South Carolina. The epicenter was just to the west of K- and C-Areas. The acceleration produced by the earthquake was estimated to be less than 0.002g (Stephenson, Talwani, and Rawlins, 1985).

3.1.4.5 Streambed Sediments

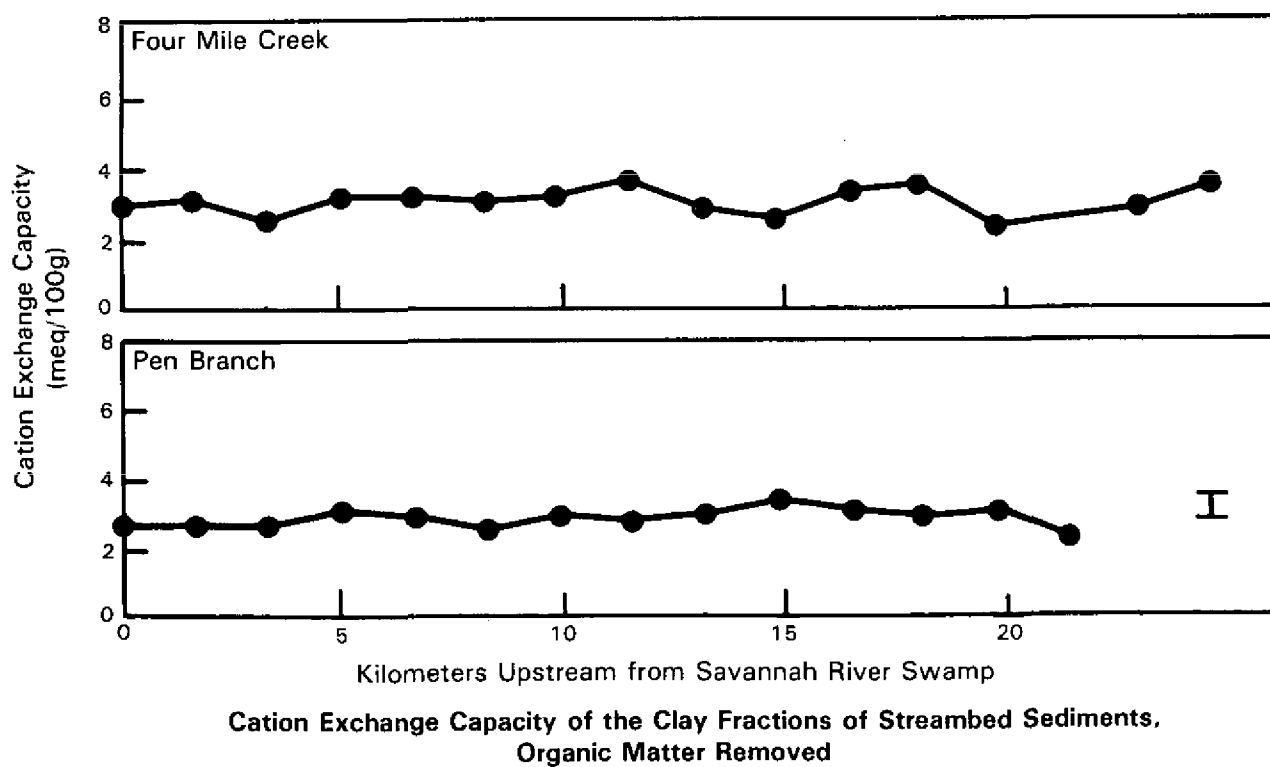
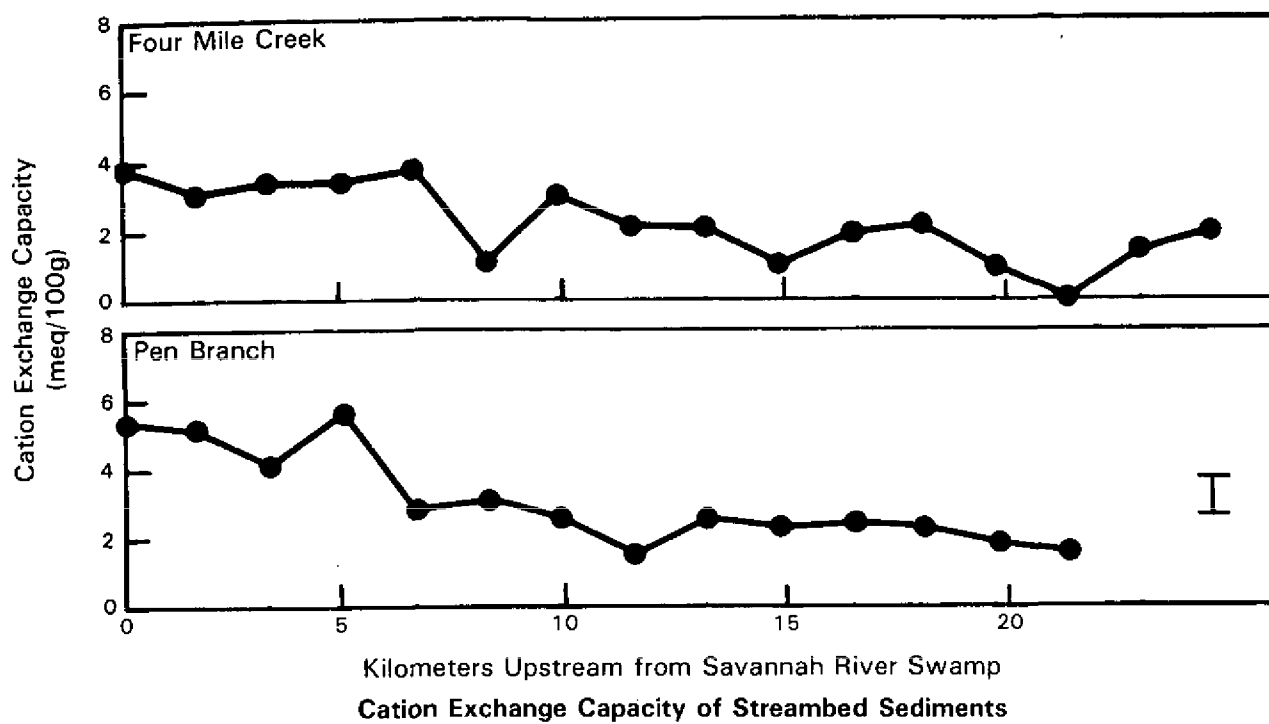
Most of the cesium-137 that has been discharged to SRP creeks by Plant operations and by fallout from offsite weapons testing is associated with the silts and clays found in the streambed and with suspended solids. The principal mechanisms for this association are (1) cation exchange with kaolinite and gibbsite clay minerals; (2) sorption on minerals; and (3) chelation with naturally occurring organic material. Figure 3-7 shows the variation in ion-exchange capacity, clay content, and content of organic materials along the course of Four Mile Creek and Pen Branch. A distribution coefficient of $K_d = 3960$, measured for sediments from Four Mile Creek (Kiser, 1979), and the work by Prout (1958) demonstrate the affinity of cesium-137 for the sediments and suspended solids in the system.

The mineral composition of each particle-size fraction of the stream sediment was observed to be quite uniform. Quartz was found to account for 80 percent of the sand and 90 percent of the silt-size fraction; kaolinite dominated the clay-size fraction (Hawkins, 1971). Minor gibbsite was found in approximately half of the sediment and soil samples, regardless of location.



Note: Range in 9 soils from source area of sediments
 Source: Hawkins (1971)

Figure 3-7. Characteristics of Streambed Sediments, Four Mile Creek and Pen Branch



Note: Range in 9 soils from source area of sediments
 Source: Hawkins (1971)

Figure 3-7. Characteristics of Streambed Sediments, Four Mile Creek and Pen Branch (continued)

The cation-exchange capacity (CEC) of sediment generally increases as particle size decreases, because of an increase in organic matter, clay-mineral content, and surface area in the finer fractions. Upstream samples contain less clay and organic matter and have lower CEC values than those from near the Savannah River swamp. Overall, the CEC of all samples was very low because of the paucity of organic matter (1.26 percent sediments, 1.52 percent soils) and the predominance of kaolinite. Kaolinite has the lowest CEC of the common clay minerals; the CEC for SRP soils and sediment typically ranges from about 1.5 to 15.2 milliequivalents per 100 grams (Siple, 1967).

As a result of these affinities, sedimentation and sorption processes control the distribution of cesium-137. The resuspension, transport, and deposition of sediment are governed by the hydraulic properties of the sediment and streambed and by the creeks varied flow regime as a consequence of reactor operations. In addition, the finegrained creekbed and floodplain sediments (clay and silt) are usually associated with higher cesium-137 concentrations than are the coarser grained sediments.

Since the early 1950s, the flow regimes of Four Mile Creek and Pen Branch, including Indian Grave Branch, have been increased by the discharge of cooling water and process effluent directly into the creeks. The drainage patterns of the two creeks changed with erosion in the stream channels and deposition near the point of discharge to the swamp. Deltas developed in the swamp. Depositional environments in both creeks presently extend from their deltas to about 2.4 kilometers below SRP Road A, where near-neutral (neither erosion nor deposition) conditions exist (Ruby, Rinehart, and Reel, 1981).

3.1.4.6 Geotechnical Properties of Sediments and Subsurface Materials*

TC

Near the center of the Savannah River Plant, the Congaree Formation (25 to 30 meters thick) consists of interfingered beds of very dense sands [SC and SM, according to the Unified Soil Classification System (Lambe and Whitman, 1969)] with stiff silts. Near its contact with the overlying McBean Formation, the Congaree is characterized by a silty to sandy marl. Exploratory drilling showed that penetration resistance [as measured by the standard penetration test (SPT) (Lambe and Whitman, 1969)] of the Congaree Formation is consistently very high, frequently greater than 50 blows per 30 centimeters of penetration. Geophysical surveys indicate a shear-wave velocity of about 470 meters per second over the entire thickness of the Congaree Formation.

A stiff to hard, glauconitic-clay to marl unit, which thickens from about 2 meters in the central portion of the Plant to about 18 meters in the south-southeast portion, separates the McBean Formation from the Congaree Formation. This clay is known locally as the "green clay."

TE

The McBean Formation, about 18 to 21 meters thick in the central region of the Plant, is composed of sands (SM, SP), clay sands (SC), silts (ML, MH), and clays (CL, CH) in the upper section, and of impure calcareous sands (SM, SC) and silts (ML); indurated broken to slightly broken marl and fossiliferous limestone might be present in the lower section. Exploratory borings have

*Formation terminology after Siple, 1967.

TC

encountered very soft plastic-clay lenses within and immediately overlying the calcareous sediments. Portions of the calcareous zone, where present, have been subjected to the subsurface leaching of appreciable amounts of calcareous material. Thus, this zone is characterized by high penetration resistance where the material is competent, and very low penetration resistance, with drops of drilling rods of 2 to 3 meters and loss of drilling fluids, where dissolution and removal of material have occurred. The U.S. Army Corps of Engineers grouted the calcareous zone beneath major structures when the facilities on the Plant were constructed in the early 1950s (COE, 1952). The zone with dissolution characteristics immediately overlies an impure limestone that is characterized by high blow counts. The limestone units are discontinuous; where they are present, the upper surface of the limestone is generally irregular and undulatory. Above the basal calcareous zone, the sands of the McBean are medium-dense with penetration resistance typically in the range of 10 to 30 blows per centimeters. In some areas, such as stream valleys, the upper McBean sands can be in a very loose to loose state. Except in stream valleys, shear-wave velocities are expected to range from about 300 meters per second in the upper portion of the formation to 440 to 470 meters per second in the lower portion.

TE | A discontinuous clay unit (approximately 3.5 meters thick) known locally as the "tan clay" separates the McBean Formation from the overlying Barnwell Formation. The total thickness of the Barnwell in the central portion of the Plant is about 25 meters, but it varies depending on the amount of erosion that has occurred. The sands of the Barnwell Formation are typically classified as SC and SM with some SP material, whereas the clayey material is usually classified as CL, ML, and MH. Penetration resistance in the Barnwell is frequently low, with the sandy material exhibiting loose to very loose densities and the clays soft to very soft consistencies. Two zones of loosely compacted material have been identified, one near the top of the formation and the other near its base. In these zones, the penetration resistance is usually less than 4 blows per 30 centimeters.

Undifferentiated floodplain alluvial sediments consist of interfingering lenses of inorganic, very loose to loose and medium-dense sands (SP), gravels (GM-GP), and clay-sand mixtures (SM and SC). The very soft and soft inorganic and organic silts (ML, MH, and OH) and clays (GC) of this zone have also been encountered in floodplain sediments. Typical deposits are about 5 meters thick in the center of the valley and pinch out toward the valley walls. Colluvial deposits are located on the flanks of the stream valleys and are partially mixed with the floodplain sediments. They are composed of reworked sediments of the McBean and Barnwell Formations and form a drape 3 or more meters thick over the valley slopes.

The potential for settlement and liquefaction exists beneath structures founded above areas with low penetration resistance.

3.1.5 HYDROLOGY

3.1.5.1 Surface-Water Hydrology

The principal surface-water body associated with the Plant is the Savannah River, which adjoins the site along its southwestern border. The total drainage area of the river, 27,388 square kilometers, encompasses all or parts of

41 counties in Georgia, South Carolina, and North Carolina. More than 77 percent of this drainage area lies upriver of the Plant (Lower, 1985). On the Plant, a swamp lies in the floodplain along the Savannah River for a distance of about 16 kilometers; the swamp is about 2.4 kilometers wide.

Six principal tributaries to the Savannah River are located on the SRP site: Upper Three Runs Creek, Beaver Dam Creek, Four Mile Creek, Pen Branch, Steel Creek, and Lower Three Runs Creek (Figure 3-2). Five of these onsite streams have historically received thermal discharges from SRP cooling water operations. Currently, only Beaver Dam Creek, Four Mile Creek, and Pen Branch are receiving direct thermal discharges from the D-Area coal-fired powerhouse, C-Reactor, and K-Reactor, respectively. Both L-Reactor and P-Reactor discharge to cooling impoundments before the effluent is released to Steel Creek and Lower Three Runs Creek, respectively. The P-Reactor effluent is recirculated in Par Pond prior to discharge, whereas L-Reactor discharges its cooling effluent to a "once-through" cooling impoundment. No direct discharge of SRP cooling water is made to the Savannah River.

Streamflow Characteristics

Natural discharge patterns on the Savannah River are cyclic: the highest river levels are recorded in the winter and spring, and lowest levels are recorded in the summer and fall. Stream flow on the Savannah River near the Plant is regulated by a series of three upstream reservoirs: Clarks Hill, Russell, and Hartwell (DOE, 1984b). These reservoirs have stabilized average annual stream flow to 288.8 cubic meters per second near Augusta (Bloxham, 1979) and 295 cubic meters per second at the Savannah River Plant (DOE, 1984b).

The river overflows its channel and floods the swamps bordering the Plant when its elevation rises higher than 27 meters above mean sea level (which corresponds to flows equal to or greater than 438 cubic meters per second) (Marter, 1974). River-elevation measurements made at the SRP Boat Dock indicate that the swamp was flooded approximately 20 percent of the time (74 days per year on the average) during the period from 1958 through 1967.

The peak historic flood between the years 1976 and 1981 was estimated to be 10,190 cubic meters per second (DOE, 1984b). Since the construction of the upstream reservoirs, the maximum average monthly flow has been 1242 cubic meters per second for the month of April (1964-1981).

There are three significant breaches in the natural river levee at the SRP site; they are opposite the mouths of Beaver Dam Creek, Four Mile Creek, and Steel Creek. During periods of high river level (above 27 meters), river water overflows the levee and stream mouths and floods the entire swamp area. The water from these streams then flows through the swamp parallel to the river and combines with the Pen Branch flow. The flows of Steel Creek and Pen Branch converge 0.8 kilometer above the Steel Creek mouth. However, when the river level is high, the flows are diverted parallel to the river, across the offsite Creek Plantation Swamp; ultimately they join the Savannah River flow near Little Hell Landing (DOE, 1984b).

Water Quality

Historically, the Savannah River has been subjected to many factors that affect the water quality. Completion of the Clarks Hill Dam, located upstream from the Plant at River Mile 237.7, resulted in decreased silt loading and turbidity downstream. Because of the depth of withdrawal, the temperature of the water decreased by about 5°C (Neill and Babcock, 1971). From 1951 until 1956, downstream reaches of the Savannah River were dredged to improve channel alignment and navigability. This dredging temporarily increased suspended solids, turbidity, and dissolved nutrients.

Improved wastewater treatment by municipalities since the mid-1960s has reduced the nutrient loading and biochemical oxygen demand; however, industrialization of the river basin in the metropolitan Augusta, Georgia, area has increased total waste loading (DOE, 1982).

Variability of all water-quality parameters has diminished over the last 20 years, primarily because of flow stabilization by upstream dams. The pH of the river is generally slightly acid. The river water is relatively soft, well oxygenated, and low in chemical and biological oxygen demand (Lower, 1984). Table 3-3 compares the 10-year mean Savannah River water quality measurements upriver, at, and downriver of the Plant.

The annual average temperature of the Savannah River 3 kilometers upriver of the Plant, from 1979 to 1982, was 17.8°C with a range of individual sample analyses of 1.5° to 26.0°C. Similarly, below the Plant the average annual temperature was 18.4°C and the range was 6.5° to 26.0°C. Figure 3-8 shows monthly average daily-maximum temperatures above and below the Plant from 1971 to 1983. The river temperature increased by about 1.0°C on the average over the 18 river miles between Ellenton Landing and Millet, South Carolina, below Steel Creek. This increase was due, in part, to natural warming as the water tended toward its equilibrium temperature as the result of impoundments upstream.

As shown in Figure 3-8, June, July, August, and September are the warmest river-temperature months. The average river temperature during these months was about 25 percent higher than the annual average river temperature. From June 1955 through September 1982, the river temperature at Ellenton Landing equaled or exceeded 28°C three times and equaled or exceeded 28.3°C once (DOE, 1984b).

Water Usage

The Savannah River downstream from Augusta, Georgia, is classified by the State of South Carolina as a Class B waterway, suitable for agricultural and industrial use, the propagation of fish, and - after treatment - domestic use. The river upstream from the Plant supplies municipal water for Augusta, Georgia (River Mile 187), and North Augusta, South Carolina (River Mile 201). Downstream, the Beaufort-Jasper Water Authority in South Carolina (River Mile 39.2) withdraws water to supply a population of about 51,000. The Cherokee Hill Water Treatment Plant at Port Wentworth, Georgia (River Mile 29.0), withdraws water to supply a business-industrial complex near Savannah, Georgia, that has an estimated consumer population of about 20,000 (Du Pont, 1982b). Plant expansions for both systems are planned for the future.

Table 3-3. Water Quality of the Savannah River, 1973 to 1982
Upriver of the SRP, at Pumphouse 3G and Downriver
at the U.S. Highway 301 Bridge^a

Parameter	Upstream of SRP mean concentration, 1973-1982 (mg/l ^b) RM 158.5	Pumphouse 3G mean concentration, 1973-1982 (mg/l ^b) RM 155.5	Hwy. 301 Bridge mean concentration, 1973-1982 (mg/l ^b) RM 118.7
Temperature (°C)	17.7	19.0	18.1
pH (units) (range)	5.3-7.6	5.3-8.0	5.5-7.3
Dissolved oxygen	9.6	9.7	9.5
Alkalinity	13.8	17.7	13.9
Conductivity (µmhos/cm)	66.8	NA	67.9
Suspended solids	17.1	24.1	16.2
Volatile solids	23.4	22.1	23.3
Total dissolved solids	47.9	58.6	48.2
Total solids	65.2	83.0	65.7
Biochemical oxygen demand	1.6	0.73	1.5
Chemical oxygen demand	NA ^c	10.7	NA
Chlorides	5.3	6.2	5.1
Kjeldahl nitrogen (N)	NA	1.0	NA
Nitrates + nitrites (N)	0.693	0.294	0.637
Sulfates (SO ₄)	5.17	4.34	5.14
Total phosphates (PO ₄)	0.464	0.098	0.421
Aluminum (Al)	0.382	0.97	0.443
Ammonia (N)	0.108	0.147	0.090
Calcium (Ca)	2.24	3.66	2.23
Sodium (Na)	7.66	9.33	7.24
Iron, total (Fe)	0.34	0.90	0.32
Lead (Pb)	NA	0.42	NA
Manganese (Mn)	NA	0.01	NA
Mercury (Hg)	0.002	0.001	0.002

a. Source: Du Pont, 1985b.

b. Except as noted.

c. NA - No analysis.

The Savannah River Plant currently withdraws a maximum of 37 cubic meters per second (about 90 percent of the maximum pumping rate of 41 cubic meters per second) from the river, primarily for use as cooling water in production reactors and coal-fired powerhouses (DOE, 1984b). Almost all this water returns to the river via SRP streams; consumptive water use is about 0.9 cubic

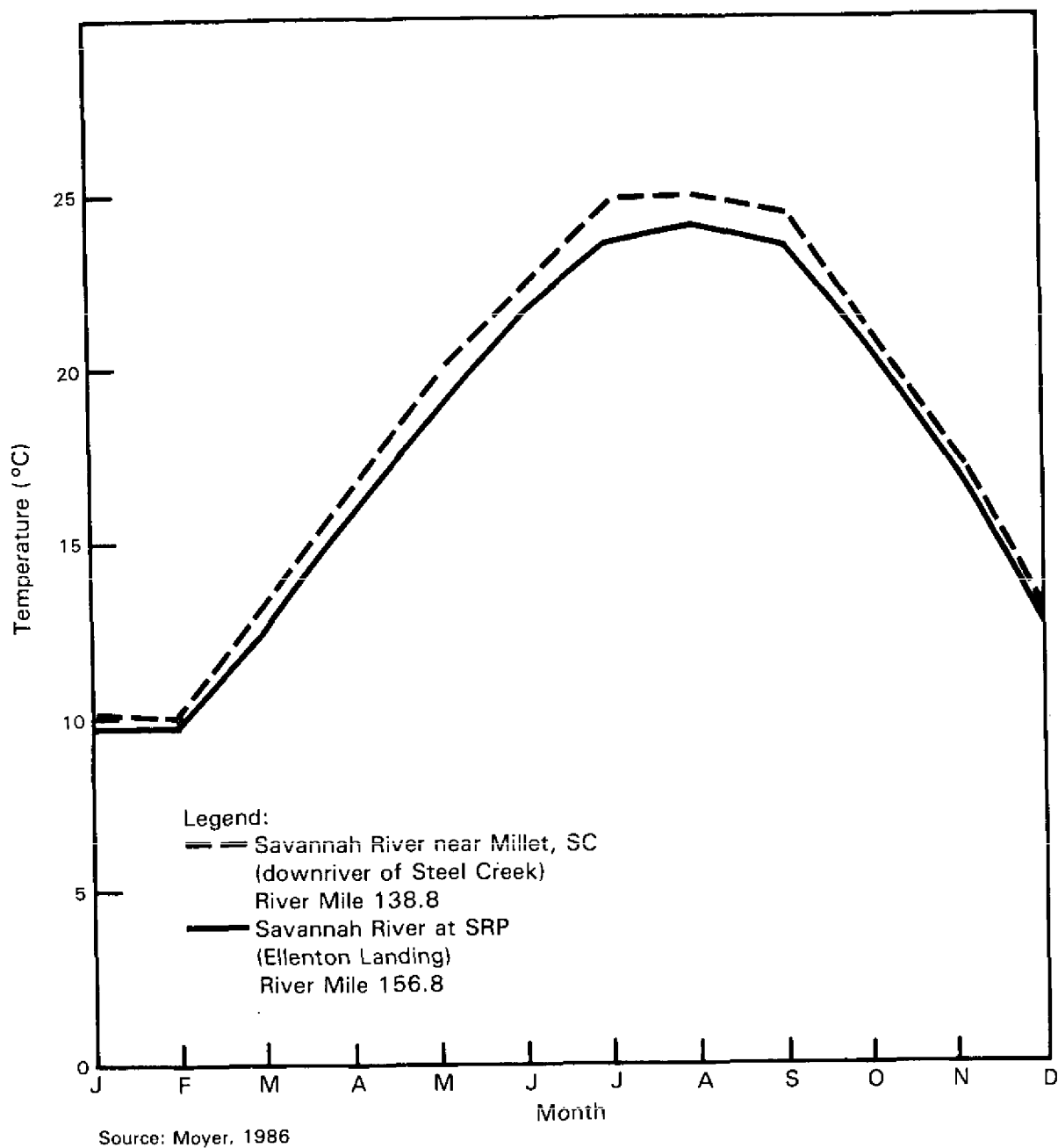


Figure 3-8. Savannah River Monthly Average Daily-Minimum Temperatures for 1971-1983

meter per second at K- and C-Reactors, 1.3 cubic meters per second at L- and P-Reactors, and about 0.3 cubic meter per second at the D-Area coal-fired powerhouse (DOE, 1984b).

The river also receives sewage treatment plant effluents from Augusta, Georgia; North Augusta, Aiken, and Horse Creek Valley, South Carolina; and other waste discharges along with the heated SRP cooling water via its tributaries. Withdrawal of an average of 1.3 cubic meters per second from the river for cooling and the return of an average of 0.35 cubic meter per second from unit one of the Vogtle Electric Generating Plant began in 1987. These withdrawal and return rates would double when both units were operating (NRC, 1985). The Urquhart Steam Generating Station at Beech Island withdraws approximately 7.4 cubic meters per second of once-through cooling water. Upstream, recreational use of impoundments on the Savannah River, including water contact recreation, is more extensive than it is near the Plant and downstream. No uses of the Savannah River for irrigation have been identified in either South Carolina or Georgia (Du Pont, 1982b).

TC

3.1.5.2 Subsurface Hydrology

The geologic units that underlie the Savannah River Plant are components of the hydrogeological system of the area (see Figure 3-6). Here the Coastal Plain sedimentary units that transmit water consist of the Barnwell (combined with the overlying Hawthorn as one mapping unit), McBean, Congaree, Ellenton, and Middendorf/Black Creek ("Tuscaloosa") Formations (Figure 3-6). The principal confining and semi-confining units include the "tan clay," which separates the Barnwell and McBean Formations, the "green clay," which separates the McBean and Congaree Formations, the basal Congaree and Ellenton clays, and the clay units in the Middendorf/Black Creek (Figure 3-9). South and east of Upper Three Runs Creek, the water table (or unconfined groundwater) generally occurs in the Barnwell Formation. Groundwater in the underlying units occurs under semiconfined and confined conditions.

TE

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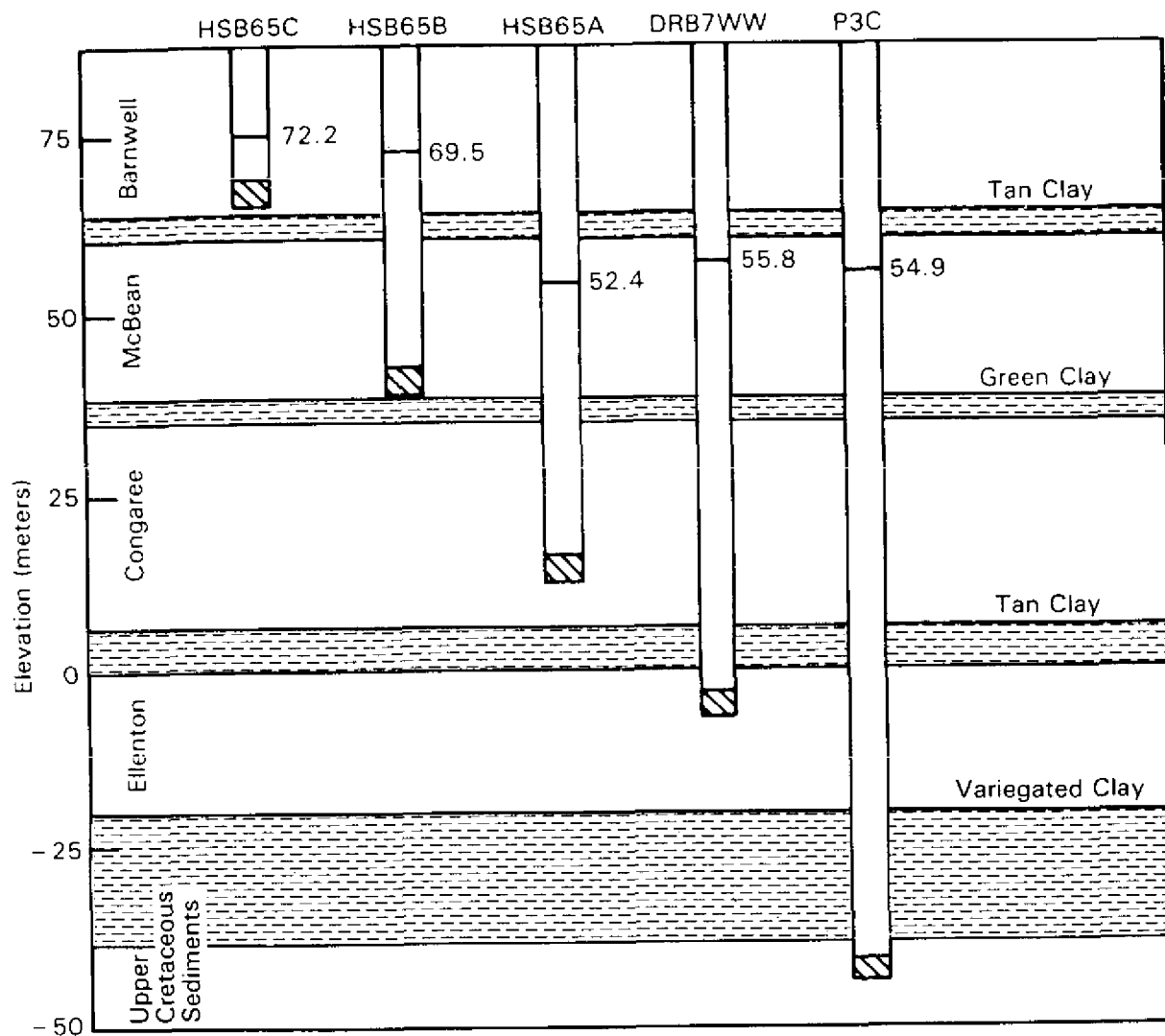
The Barnwell Formation at the Plant is recharged by precipitation, which moves in a predominantly vertical direction to the water table at a rate of about 0.9 to 2.1 meters per year (Haskell and Hawkins, 1964). Natural discharge from the Barnwell Formation is to the perennial creeks and to the McBean Formation. From a water budget analysis for the central part of the Plant, Hubbard and Emslie (1984) estimated that the annual recharge to the Barnwell Formation is about 38 centimeters with about 13 centimeters of groundwater discharging to the creeks and 25 centimeters seeping through the "tan clay" to the McBean Formation.

The McBean Formation is recharged in offsite areas and by seepage from the Barnwell Formation. Natural discharge is toward Upper Three Runs Creek, Four Mile Creek, Pen Branch, and Indian Grave Branch, which is a tributary of Pen Branch.

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The Congaree Formation is recharged in offsite areas and by seepage from the McBean Formation. Natural discharge is toward the wetlands along Upper Three Runs Creek and the Savannah River. There is no appreciable seepage downward through the Ellenton clay or upward through the "green clay." As a result of

TC



Source: Du Pont, 1985a. Hydrostratigraphic unit terminology after Siple, 1967; see Figure A-2.

Legend:

-  Clay layer
-  Screen zone

Note: Water levels in HSB65A, B, and C measured 3/8/85
Water levels in DRB7WW and P3C measured 3/18/85

Figure 3-9. Vertical Head Relationship Near the H-Area Seepage Basins

the natural discharge, the potentiometric head in the Congaree is lower than that in the Middendorf/Black Creek Formations in a broad area within about 10 kilometers of Upper Three Runs Creek and the Savannah River. | TE

The Middendorf/Black Creek Formations are recharged in offsite outcrop areas near the Fall Line in Aiken County, and through the overlying sediments north and west of Upper Three Runs Creek. Natural discharge is toward the wetlands along the Savannah River north of the Plant. Water is also lost from seepage into overlying formations. | TE
| TC

The water in the Coastal Plain sediments tends to be of good quality, suitable for municipal and industrial use with minimal treatment. It is generally soft, slightly acid, and low in dissolved and suspended solids.

Most municipal and industrial water supplies in Aiken County are developed from the Middendorf/Black Creek ("Tuscaloosa") Formations. Domestic water supplies in Aiken County are developed primarily from the Barnwell, McBean, and Congaree Formations. In Barnwell and Allendale Counties, the Middendorf/Black Creek Formations occur at increasingly greater depths; some municipal users, therefore, are supplied from the shallower Congaree and McBean Formations or from their limestone equivalent. In these counties, domestic supplies are developed from the Barnwell and McBean Formations. | TE
| TE

3.1.6 ECOLOGY

The United States Government acquired the 780-square-kilometer (192,741 acres) Savannah River Plant in 1951 (Du Pont, 1985b). At that time the land was approximately two-thirds forested and one-third cropland and pasture (Dukes, 1984). With the exception of the production and support areas, many previously disturbed areas and open fields have been reclaimed by natural succession or have been planted with trees; these areas are managed by the U.S. Forest Service. Today more than 90 percent of the Plant is forested. Table 3-4 lists recent SRP land utilization, other than the land used for chemical or nuclear processes and support facilities. The Plant, which was designated as a National Environmental Research Park in 1972, is one of the most extensively studied environments in this country (DOE, 1984b). | TC

This section describes the ecology of the Savannah River Plant and the surrounding region. Appendix C presents results of many studies conducted in the Savannah River, the Savannah River swamp, and the onsite streams.

3.1.6.1 Terrestrial Ecology

Soils

A general soils map of the Savannah River Plant (Adelott, 1977) grouped the soil types into 23 mapping units. The dominant types are Fuquay/Wagram Soils (27.3 percent), Dothan/Norfolk soils (9.6 percent), Savannah River Swamp and Lower Three Runs Corridor (9.4 percent), Troop Loamy Sand, Terrace phase (8.4 percent), Gunter Sand (7.5 percent), and Vaucluse/Blanney Soils (6.5 percent). Together these units account for approximately 70 percent of the soil types that occur on the Savannah River Plant.

Table 3-4. Land Utilization, 1983^a

Land	Area (acres)
Open fields	650
Slash pine	35,000
Longleaf pine	37,500
Loblolly pine	48,000
Pine-hardwood (60% pine)	4,000
Hardwood-pine (60% hardwood)	6,300
Scrub oak	2,000
Upland hardwoods	4,500
Bottomland hardwoods	29,000
Other pine	100
Subtotal	167,050
<u>Wetlands</u>	
Creeks/floodplains	24,500
Savannah River Swamp	10,000
Par Pond	2,500
Carolina bays	1,000
Other	1,000
Subtotal	39,000
Total	206,050 ^b

a. Adapted from Dukes, 1984.

b. Exceeds total acreage of the Savannah River Plant because of overlap in wetlands and bottomland hardwood acres.

Vegetation

The Savannah River Plant is near the line that divides the oak-hickory-pine forest and the southern mixed forest. Consequently, it has species representative of each forest association (DOE, 1984b). In addition, SRP vegetation has been influenced strongly by farming, fire, soil features, and topography. No virgin forest remains in the region. Except for the production areas and their support facilities, the U.S. Forest Service has reclaimed many previously disturbed areas through natural plant succession or by planting with pine (Du Pont, 1985b).

A variety of vascular plants (150 families, 1097 species) occur on the Savannah River Plant (Dukes, 1984). (See Appendix C for greater detail and Appendix F for a discussion of wetlands and floodplains.) Typically, scrub oak communities cover the drier sandy areas; longleaf pine, turkey oak, bluejack oak, blackjack oak, and dwarf post oak with ground cover of three awn grass and huckleberry dominate such communities. Oak-hickory hardwoods are prevalent on more fertile, dry uplands. The characteristic species are white

oak, post oak, southern red oak, mockernut hickory, pignut hickory, and loblolly pine with an understory of sparkleberry, holly, greenbrier, and poison ivy.

The composition is more variable on moist soils found along small streams or on old floodplains. Characteristic species include tulip poplar, birch, sweet gum, willow oak, water oak, and loblolly pine. The understory can include dogwood, members of the honeysuckle family, holly, and red buckeye.

Bottomland hardwood forest borders the Savannah River swamp where it is subject to occasional flooding. Some common trees are sweet gum, swamp chestnut oak, red maple, hackberry, laurel, blue birch, river birch, water oak, willow, sycamore, winged elm, and loblolly pine. Palmetto, switch cane, greenbrier, grape, crossvine, and trumpet creeper are also common.

The swamp bordering the Savannah River is subjected to seasonal flooding with winter and early spring water levels 3 to 4.5 meters higher than those of summer and fall. Bald cypress and tupelo gum are the dominant trees in the Savannah River swamp, where standing water is present almost year-round. Black gum and water oak are also present.

The status of the smooth coneflower (*Echinacea laevigata*), which is found on the Savannah River Plant along the Burma Road, as a threatened and endangered species is currently under status review by the U.S. Fish and Wildlife Service (Currie, 1985). To date, the U.S. Fish and Wildlife Service has not identified any "critical habitat" on the Savannah River Plant. Commercially valuable plant biota on the Savannah River Plant include approximately 175,000 acres of timber managed by the U.S. Forest Service.

Wildlife

The diversity and abundance of wildlife that inhabit the Savannah River Plant reflect the interspersed and heterogeneity of the habitats occurring at the site. Because of its mild climate and the variety of aquatic and terrestrial habitats, the Savannah River Plant contains a varied and abundant herpetofauna (DOE, 1984b). Gibbons and Patterson (1978) provide a comprehensive description of the herpetofauna of the site, including taxonomy, distribution, and ecological information. The species on the Plant include 31 snakes, 26 frogs and toads, 17 salamanders, 10 turtles, 9 lizards, and 1 alligator (Dukes, 1984).

Species collected during intensive field studies on Steel Creek, particularly during 1981 and 1982, are considered to be representative of species occurring on similar creeks and wetland areas. Frogs and toads, turtles, and salamanders (in order of decreasing relative abundance) constituted more than 85 percent of the 65 species (69 percent of those on the Plant) found (DOE, 1984b).

Biologists have identified more than 213 species of resident and migrant birds on the Plant. Gamebirds such as quail and dove were initially abundant on the Plant but have declined since the 1960s because the conversion of agricultural fields to forests has reduced the carrying capacity for these species. The

South Carolina Wildlife and Marine Resource Department initiated a turkey-breeding program on the Plant in 1972. As of 1984, about 135 turkeys had been captured and used to restock other areas of the State (Dukes, 1984).

TC | Waterfowl on the Plant are mainly winter migrants. Wood ducks are the only waterfowl species to breed consistently in the SRP region. An estimated 10,000 to 15,000 ducks and coots spend the winter on the site; most congregate on Par Pond and on other large ponds and Carolina bays. Another 1000 to 2000 ducks spend the winter in the lower swamps and on the Savannah River (Dukes, 1984).

Commercially and Recreationally Valuable Biota

TC | The ecosystems on the Savannah River Plant support many commercially and recreationally valuable game populations; however, DOE restricts recreational use to controlled hunts for white-tailed deer and feral hogs. Many species are highly mobile and travel offsite where activities such as hunting are allowed. Other resident species that are edible and that travel offsite include the ring-neck duck, wood duck, mallard, bullfrog, and various species of turtles. The slider turtle is the most abundant turtle known to migrate offsite; other common species that move offsite include the Florida cooter and the snapping turtle (DOE, 1984b).

Endangered and Threatened Species

TC | Four species listed as either threatened due to similarity of appearance or endangered by the U.S. Fish and Wildlife Service - the American alligator, the bald eagle, the wood stork, and the red-cockaded woodpecker - have been identified on the SRP. As stated above for plant species, the U.S. Fish and Wildlife Service has not identified any "critical habitat" for animal species on the Savannah River Plant. (See Appendix C for more detail, especially concerning definition of "threatened due to similarity of appearance.")

TC | Listed Federally as "threatened due to similarity of appearance," the American alligator is common locally and breeds in Par Pond, near D-Area, in the Savannah River Swamp, along Steel Creek, in Pond B, and in Lower Three Runs Creek. The ecology of this species on the Savannah River Plant has been examined intensively (Du Pont, 1985b).

TC | The Federally endangered bald eagle is a fairly common permanent breeding resident in South Carolina. Bald eagles migrate from the southeast to the northern states and Canada in midsummer; they return south in the fall and early winter to nest and rear their young (Sprunt and Chamberlain, 1970). The first sighting of an active bald eagle nest on the SRP occurred in June 1986, below Par Pond dam in the Lower Three Runs Creek drainage area. Two eaglets were fledged from this nest in 1986 and 1987.

TE | Endangered wood storks, which have been observed on the Savannah River Plant, originate from the Birdsville rookery near Millen, Georgia. The Steel Creek delta, Beaver Dam Creek area, and other sites in the Savannah River swamp provide important feeding habitat for storks from this rookery (Du Pont, 1985b).

The endangered red-cockaded woodpecker has a very restrictive requirement for nesting habitat; it nests only in old (more than 50 years) stands of pines. In 1987, the SRP had three active breeding pairs and a total population of 14 (A. B. Gould, U.S. Department of Energy, personal communication with J. L. Oliver, NUS Corporation, August 20, 1987).

TC

3.1.6.2 Aquatic Ecology

Aquatic Flora

The Savannah River is the dominant water body associated with the Savannah River Plant. The river has experienced two significant alterations since the early 1950s: (1) dredging in the main channel as far as Augusta, Georgia, and (2) completion of upstream reservoirs (Clarks Hill in 1952; Hartwell in 1961; Russell in 1984). These changes have affected the aquatic community by reducing shallow habitat and reducing transport of sediment and allochthonous particulate organic material (Patrick et al., 1967). The microflora of the Savannah River is dominated by diatoms, although blue-green algae are sometimes common upstream from the Plant; their abundance is caused by organic loading from municipal sources. The abundance and species distribution of phytoplankton result, to some extent, from upstream reservoir overflow. Macrophytes, most of which are rooted, are limited to shallow areas of reduced current, such as oxbows, behind sandbars, in swamp areas, and along the shallow margins of tributaries. Eight species of vascular plants have been identified from the Savannah River adjacent to the Plant; the most common are water milfoil, hornwort, alligatorweed, waterweed, and duck potato (DOE, 1984b).

Aquatic Fauna

Shallow areas and quiet backwaters and marshes of the Savannah River near the Plant support a diverse aquatic invertebrate fauna. However, the bottom substrate of most open portions of the river consists of shifting sand that does not provide optimum habitat for bottom-dwelling organisms. During the 1950s, the river experienced a decrease in the total number of invertebrate species; this decrease has been attributed primarily to the effects of dredging (Patrick et al., 1967). The stabilization of the river discharge and the elimination of habitat caused by the reduction in the flooding of backwater areas might have contributed to the decline. Some recovery occurred during the 1960s and 1970s, but complete recovery has not taken place. The groups most affected are those sensitive to the effects of siltation and substrate instability. Mayflies and dragonflies predominated among insect fauna in earlier surveys. In more recent surveys, dipterans (true-flies) have been dominant (DOE, 1984b; ECS, 1985).

TE

Results of insect faunal studies conducted have indicated substantial organic loading to the river upstream from the Savannah River Plant. True-flies (particularly chironomids) dominated the drift communities, which is typical of a riverine system. Mollusks, such as snails and clams, are also an important component of the Savannah River invertebrate community. The Asiatic clam, Corbicula fluminea, is found in the river and larger tributary streams in the vicinity of the Plant (DOE, 1984b).

The Savannah River drainage is typical of southeastern coastal plain systems, exhibiting a diverse fish fauna represented by 102 species (Dahlberg and Scott, 1971). Eighty species have been found in the streams, swamp, and river near the SRP site (Paller and Osteen, 1985).

A study of certain biota in the Savannah River was initiated in July 1982 (Du Pont, 1985b). The focus of this study was to examine the occurrence, relative abundance, and distribution of adult and larval fishes in the river, the SRP intake canals, and lower reaches of tributary creeks. (See Appendix C for additional discussion.) Previous data and studies were reviewed, incorporated, or extended in this study.

TC | Researchers collected 80 fish species as part of this study. The dominant small fishes (excluding minnows) were sunfishes (especially redbreast) and flat bullheads. The dominant large fishes were bowfin, spotted suckers, and channel catfish. Other important species were largemouth bass, American eel, white catfish, longnose gar, striped mullet, silver redhorse, chain pickerel, and quillback carpsucker. The most abundant small forage species were shiners and brook silverside (Du Pont, 1985b; Paller and Osteen, 1985).

Species composition varied due to seasonal changes in fish movement and activity (e.g., spawning). The most conspicuous change was a decrease in the relative abundance of sunfish during January. Bowfin, spotted sucker, flat bullhead, and channel catfish were more abundant during January. The greatest number of species (37) was captured during May, possibly because of migratory movements or seasonal changes in activity related to spawning. Recruitment of young of the year might have increased the relative abundance of some species during August (Du Pont, 1985b).

Thermal effluents affect the structure of fish communities in the streams and swamp on the Savannah River Plant. Studies of nonthermal, thermal, and post-thermal areas in SRP stream and swamp systems indicate that the thermal streams have markedly reduced species richness and abundance in relation to ambient-temperature areas. In these ambient-temperature areas, habitat factors (cover type, water depth, water velocity) can strongly influence species composition. The greatest differences in fish community structure occurred between the swamp sites and areas sampled along the lower reaches of the Four Mile Creek corridor. Species richness declined substantially and mosquitofish clearly dominated collections. Mosquitofish were either absent or minor components of the community at ambient-temperature sites (Du Pont, 1985b).

The 1983 ichthyoplankton sampling program extended from February through July; it included 26 river transects, 2 intake canals, and 33 tributary creeks of the Savannah River between River Mile (RM) 29.6 and 187.1. During 1983, researchers collected and identified 43,294 fish larvae and 7138 fish eggs (Du Pont, 1985b).

Ichthyoplankton densities were highest downstream of the Plant during February, March, and April, highest near the Plant during May, and highest upstream of the Plant during June and July. These trends correlated with temperature and probably occurred because the lower river warmed to suitable spawning temperatures before the upper river (Du Pont, 1985b).

During March and April 1983, ichthyoplankton density decreased nearly five-fold near the Plant between RM 141.7 and RM 150.4. This phenomenon did not result from the destruction of larvae by thermal plumes from the Plant because river temperatures were not abnormally elevated in the region; nor was it due to entrainment, because only 6.6 percent of the river discharge was entrained during March and 4.2 percent in April. The marked increase in ichthyoplankton abundance below RM 150.4 probably resulted from an influx of larvae from spawning areas in the swamps bordering the Plant. When river levels are unusually high, as they were during the 1983 spawning season, SRP thermal effluents discharge into the swamp rather than directly into the main channels of the receiving streams. The resulting temperature increases in the swamp might have stimulated spawning.

Patterns in stream-swamp ichthyoplankton abundance on the Savannah River Plant were comparable with those of adult fish. Generally, ichthyoplankton densities at swamp and creek mouth stations were substantially higher than those at creek stations upstream from the swamp. Results from sampling throughout the Steel Creek delta revealed that spawning activity differs substantially in the different microhabitats available in the delta area. The deepwater, open-canopy areas were the most productive for ichthyoplankton; centrarchids (sunfish and bass), cyprinids (minnows), and percids (darters) dominated collections. Although clupeids (herring and shad) were collected in the delta/swamp areas, the numbers were much lower than those observed at creek mouth stations. Generally, anadromous species appear to make minimal use of swamp areas for spawning and restrict these activities to the creek mouths. No striped bass ichthyoplankton have been collected in swamp or creek mouth locations.

During 1984, 1938 fish were collected from impingement samples on 107 sampling dates. The number of fish impinged daily ranged from 0 to 190, with an average of 18 fish per day (Paller and Osteen, 1985). The average number of fish impinged during 1984 was approximately half of the 37 fish impinged daily during 1983 (Paller et al., 1984), but was similar to the average of 19 fish impinged during 1982 (ECS, 1983). These three years of data (1982 to 1984) indicate that more than twice as many fish are impinged as the 7 per day reported during 1977 (McFarlane, Frietsche and Miracle (1978). Generally, all researchers found that sunfishes were the most dominant fish impinged, followed by shad and herring. Highest rates of impingement generally occurred in the spring, associated with flood conditions (Du Pont, 1985b; Paller and Osteen, 1985).

Entrainment of larval fish and eggs at the SRP pumphouses during the 1984 spawning season totaled 23.4×10^6 ichthyoplankters (17.6×10^6 larvae and 5.8×10^6 eggs (Paller, O'Hara, and Osteen, 1985)), which was 37.0 percent less than the 37.2×10^6 larval and eggs entrained in 1983 (Paller et al., 1984). The 1983 and 1984 entrainment values represent 8.3 and 9.3 percent, respectively, of the total ichthyoplankton that passed by the intake canals and structures (Paller, O'Hara, and Osteen, 1985). (See Appendix C for more details concerning entrainment and impingement studies).

Endangered and Threatened Species

Recent fisheries surveys on the Savannah River revealed that the endangered shortnose sturgeon spawn in the vicinity of the Savannah River Plant (Du Pont,

1985b). Shortnose sturgeon larvae were collected in river water upstream, downstream, and adjacent to the Plant during 1982 (two larvae collected), 1983 (six collected), and 1984 (two collected). All of the sturgeon larvae collected during 1982 were taken from the section of river between RM 150.8 and RM 157.3, with none collected from the intake canals. One of the seven shortnose sturgeon larvae collected in 1983 was found in the 1G intake canal, one was found in the 3G intake canal, and the remaining five were found adjacent to or downstream of the Plant. During 1984, both shortnose sturgeon larvae were collected below the Plant. No larvae or juveniles were collected from any SRP tributary stream during 1982, 1983 (Du Pont, 1985b), or 1984 (Paller, O'Hara, and Osteen, 1985).

A biological assessment of the potential effects of SRP operations on the shortnose sturgeon in the Savannah River (Muska and Matthews, 1983) was submitted to the National Marine Fisheries Service (NMFS). The NMFS and DOE-SR have concurred that the population of the shortnose sturgeon in the Savannah River would not be jeopardized by SRP operations (Oravetz, 1983).

Commercially and Recreationally Valuable Biota

All thermal streams on the Savannah River Plant support depauperate fish populations, especially during periods of reactor operations. However, the Savannah River supports both commercial and sport fisheries (Appendix C). Most fishing is confined to the marine and brackish waters of the coastal regions of South Carolina and Georgia. The only commercial fish of significance near the Plant are the American shad, the channel catfish, and the Atlantic sturgeon. (The commercial catch of American shad from the Savannah River during 1979 was 57,600 kilograms.) These species are exploited to a limited degree by local fishermen.

Sport fishermen are the principal consumers of river fishes, primarily sunfish and crappie. Striped bass are classified as game fish in South Carolina and Georgia (Ulrich et al., 1978).

The Fisheries Section of the Georgia Department of Natural Resources (GDNR) published the results of a fisheries study conducted on the Savannah River from July 1, 1981, to June 30, 1982 (Georgia Game and Fish Division, 1982). GDNR researchers collected data from sports fishermen on fishing effort, harvest, species sought, habitat or location fished, and angler origin. Approximately 4600 anglers fish in the freshwater section of the Savannah River. Georgia residents constitute 68.2 percent of these anglers. The anglers fish in both the mainstream (58.2 percent) and oxbows, creeks, and lakes (41.8 percent) of the river. Freshwater anglers fish (43.8 percent of their time) for bream (i.e., bluegill, redbreast sunfish, warmouth, redear sunfish, and spotted sunfish); bream account for 73 percent of the fish caught. Largemouth bass is the next most popular species (38 percent of the time); however, success is low (2.5 percent of the fish caught). About 90,000 kilograms of freshwater fish are harvested from the lower Savannah River annually.

3.1.7 METEOROLOGY AND CLIMATOLOGY

The description of the meteorology of the Savannah River Plant is based on data collected at the Plant and at Bush Field in Augusta, Georgia (Du Pont,

1980a, 1982b; NOAA, 1985). Additional information in the following sections was obtained from magnetic tapes containing data from the onsite meteorological program for the period 1975 through 1979.

3.1.7.1 Regional Climatology

The SRP area has a temperate climate, with mild winters and long summers. The region is subject to continental influences, but it is protected from the more severe winters in the Tennessee Valley by the Blue Ridge Mountains to the north and northwest. The SRP site and the surrounding area are characterized by gently rolling hills with no unusual topographical features that would have a significant influence on the general climate.

Winters are mild and, although cold weather usually lasts from late November to late March, less than one-third of the days have a minimum temperature below freezing.

3.1.7.2 Local Meteorology

SRP Meteorology Data System

Meteorological data are collected from a system of seven towers located adjacent to each production area on the Plant and from the WJBF-TV tower about 15 kilometers northwest of the SRP boundary. The seven towers are instrumented at the stack height of 61 meters with vector vanes designed for turbulence measurements (Kern and Mueller, 1979). The TV tower is instrumented at seven levels (Hoel, 1983) with bivanes and fast-response cup anemometers to provide the same type of information as that received from the SRP towers (Kern and Mueller, 1979). Platinum resistance thermometers at each of eight levels on the TV tower provide temperature information on the lowest 300 meters of the atmosphere.

The data measured by this tower system are received in the Weather Center Analysis Laboratory (WCAL) on the Plant. The data collected from the SRP tower system and the WJBF-TV tower are used for real-time emergency-response situations.

In addition to the tower data, extremes in daily temperature and rainfall are recorded, and continuous measurements of temperature, relative humidity, and pressure are kept. Rain gauges are located at various locations on the SRP site.

Temperature and Humidity

Table 3-5 lists the average and extreme temperatures recorded for the Plant. The annual average temperature at the Plant is 18°C. The monthly average ranges from 7°C in January to 27°C in July (see Table 3-5). The extreme temperatures observed are -16°C and 41°C. The Augusta, Georgia, long-term temperature data are in agreement with those for the Savannah River Plant.

The length of the growing season for the Augusta area is normally 241 days, with the first freeze on November 12, and the last on March 16. Freezing temperatures have been observed, however, as early as October 17, and as late as April 21.

Table 3-5. Average and Extreme Temperatures ($^{\circ}\text{C}$) at Savannah River Plant, 1961-1981

Month	Average temperature			Extreme temperature	
	Daily maximum	Daily minimum	Monthly	Record maximum	Record minimum
Jan.	13	2	7	30	-16
Feb.	16	3	9	27	-16
Mar.	20	7	13	32	-12
Apr.	25	12	18	35	0
May	28	16	22	37	5
June	32	19	26	41	9
July	33	21	27	41	14
Aug.	32	21	27	40	13
Sept.	29	18	24	38	5
Oct.	24	12	18	33	-2
Nov.	19	7	13	32	-8
Dec.	15	3	9	28	-11
Year	24	12	18	41	-16

The annual average daily relative humidity for the Plant ranges from 43 to 90 percent.

Average Wind Speed and Direction

TE | The average annual wind speed measured in Augusta from 1951 to 1981 was 3.0 meters per second (see Table 3-6). The average annual wind speed recorded at a height of 10 meters on the WJBF-TV tower near Beech Island, about 15 kilometers northwest of the Plant, was 2.5 meters per second from 1976 to 1977. The average monthly wind speed for Augusta, Georgia, is listed in Table 3-6 along with the prevailing wind direction for each month. This table also lists the monthly and annual average wind speeds for three levels of the television tower.

TE | Annual wind-direction frequencies for the K-, C-, and D-Areas are shown in the transport plots (Figures 3-10 through 3-12). These figures show the percentage of time that the wind blows from each of 16 directions (22.5° sectors). The information presented in these figures was produced from data taken at the 61-meter level (the stack height in most SRP production areas). Seasonal transport is generally as follows: winter, northwest to southeast; spring, west to east; summer, toward the southeast through north to northeast; and autumn, toward the southwest and southeast. Because the pollutant dispersion depends on atmospheric stability, annual wind roses are available for each of the seven SRP towers for each of seven Pasquill-type stability classes; seasonal wind roses are also available (Hoel, 1983).

Table 3-6. Average Monthly Wind Speed for Bush Field, Augusta, Georgia, 1951-1981 and WJBF-TV Tower, 1976-1977

Month	Bush Field		WJBF-TV tower elevation (m)		
	Mean speed (m/sec)	Prevailing direction	10	36	91
Jan.	3.2	W	3.0	4.5	6.1
Feb.	3.4	WNW	2.9	4.6	5.8
Mar.	3.6	WNW	3.3	4.5	5.9
Apr.	3.4	SE	2.8	4.2	5.4
May	2.9	SE	2.5	3.7	5.0
June	2.8	SE	2.4	4.0	4.8
July	2.6	SE	2.0	3.1	4.4
Aug.	2.5	SE	2.1	3.2	4.3
Sept.	2.5	NE	2.1	3.3	4.7
Oct.	2.6	NW	2.4	4.1	5.6
Nov.	2.8	NW	2.4	4.1	5.6
Dec.	3.0	NW	2.7	4.4	6.3
Annual	3.0	SE	2.5	3.9	5.3

Precipitation

The average annual rainfall at the Savannah River Plant from 1952 through 1978, was about 120 centimeters (Du Pont, 1982b). The average at Augusta from 1951 to 1980 was about 113 centimeters (NOAA, 1985). Table 3-7 lists the means and extremes of precipitation for the Plant from 1952 to 1982. The maximum monthly precipitation was about 31.6 centimeters, recorded in August 1964. Hourly observations in Augusta show that the intensity of the rainfall is normally less than 1.3 centimeters per hour.

3.1.7.3 Severe Weather

Extreme Winds

The strongest winds in the SRP area occur in tornadoes, which can have wind speeds as high as 116 meters per second. The next strongest surface winds occur during hurricanes. During the history of the SRP, only Hurricane Gracie, in September 1959, had winds in excess of 34 meters per second. Winter storms with winds as high as 32 meters per second have been recorded occasionally (Du Pont, 1982b). Thunderstorms can generate winds as high as 18 meters per second and even stronger gusts. The highest 1-minute wind speed recorded at Augusta between 1951 and 1984 was 28 meters per second. Table 3-8 lists the extreme wind speeds for 50- and 100-year return periods for three locations about equally distant from the Plant (Simiu, Changery, and Filliben, 1979).

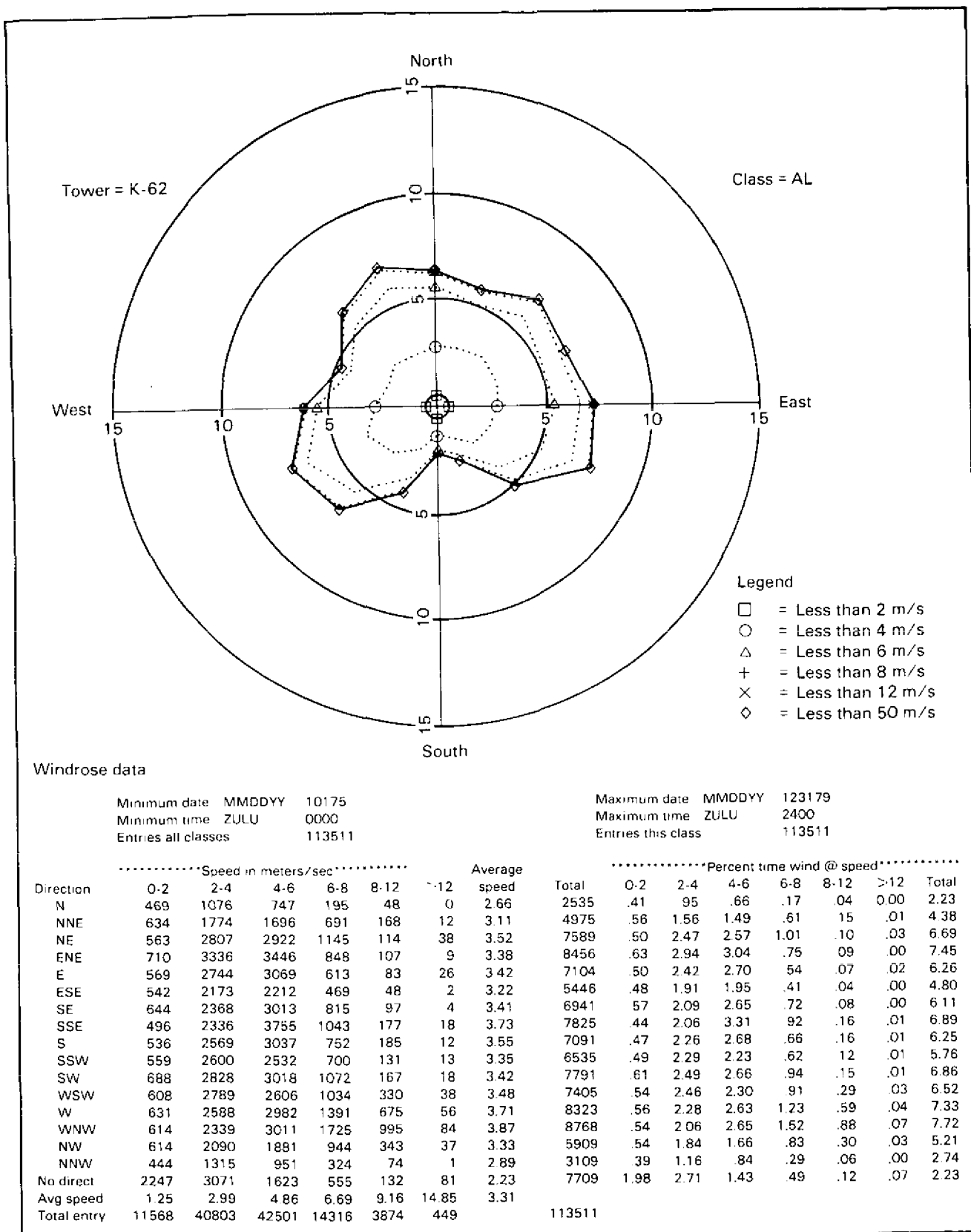
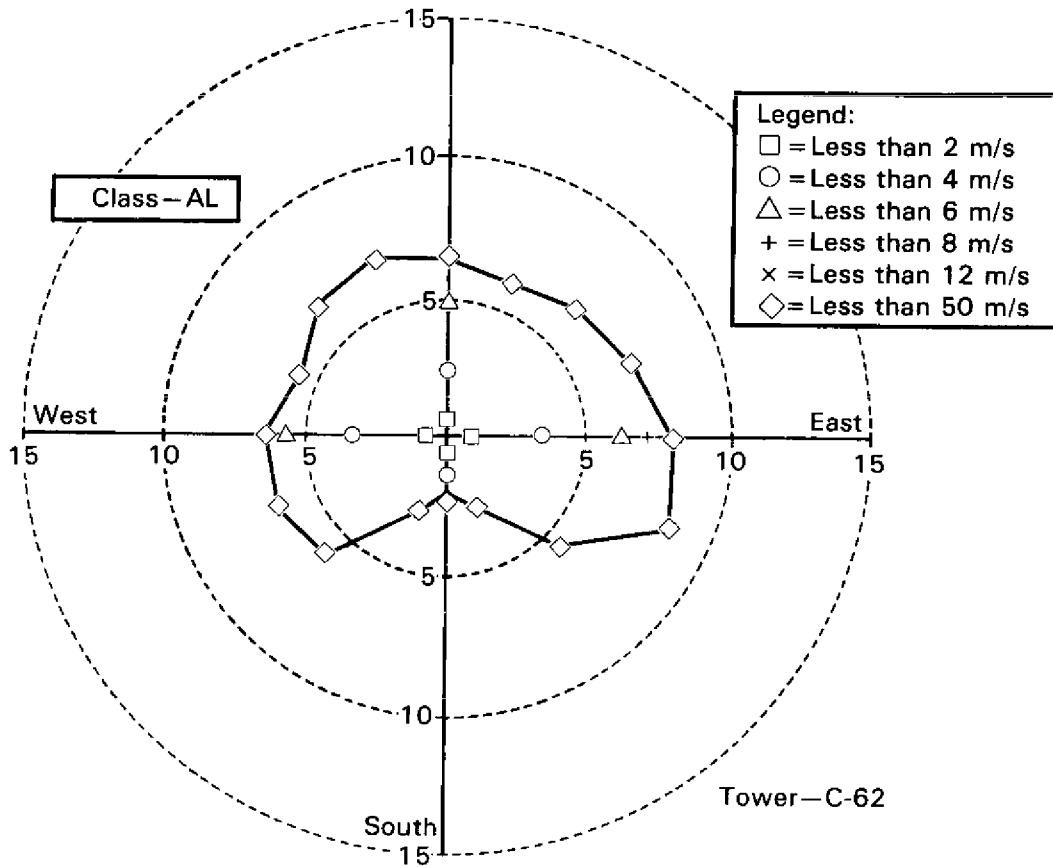


Figure 3-10. K-Area Tower 1975-1979



Windrose Data

Minimum Date MMDDYY 10175

Minimum Time ZULU 0000

Entries All Classes 114938

Maximum Date MMDDYY 123179

Maximum Time ZULU 2400

Entries This Class 114938

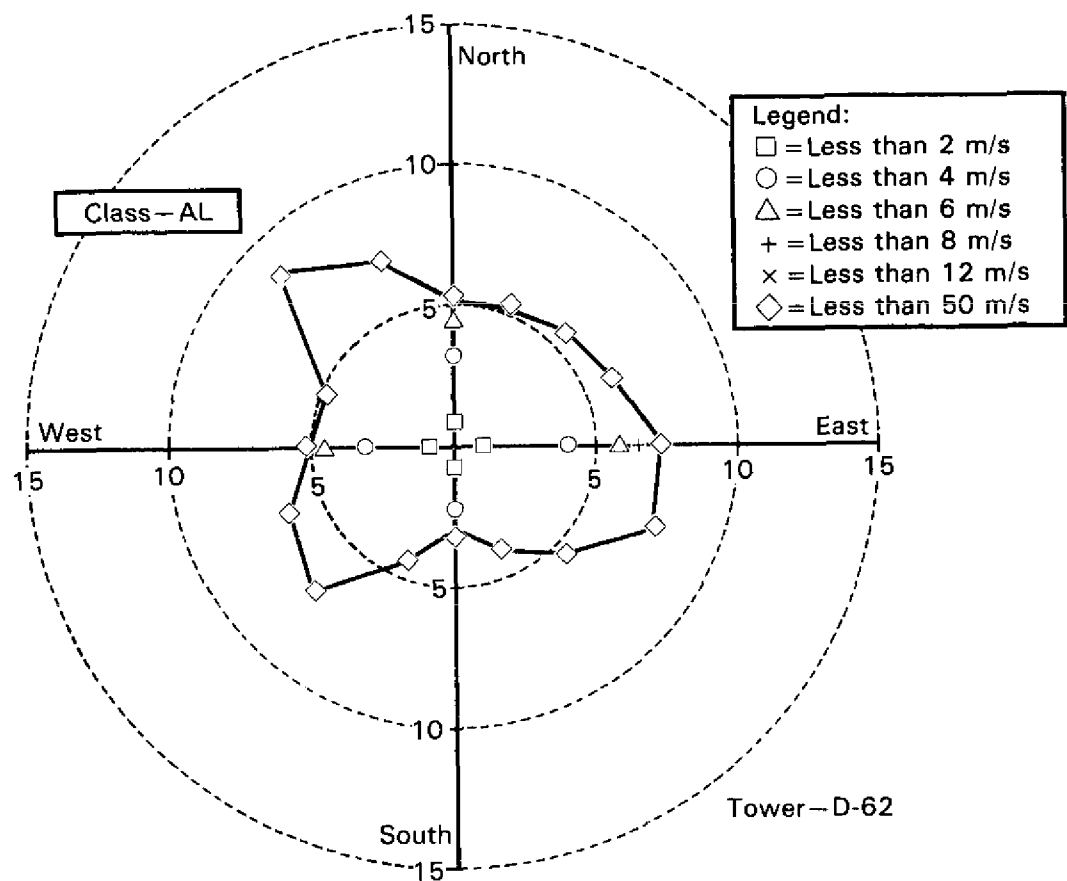
0 0 0 0 0

Speed in Meters/Sec. ■■■■■

■■■■■ Percent Time Wind & Speed ■■■■■

Direction	0-2	2-4	4-6	6-8	8-12	>12	Average Speed	Total	0-2	2-4	4-6	6-8	8-12	>12	Total
N	497	1016	665	115	2	0	2.42	2295	.43	.88	.58	.10	.00	.00	2.00
NNE	563	1457	971	330	53	0	2.77	3374	.49	1.27	.84	.29	.04	.00	2.94
NE	562	2257	2483	1288	245	10	3.55	6845	.49	1.96	2.16	1.12	.21	.00	5.96
ENE	713	2482	2934	1216	98	31	3.39	7474	.62	2.16	2.55	1.06	.08	.02	6.50
E	733	2980	2899	759	49	0	3.21	7420	.64	2.59	2.52	.66	.04	.00	6.46
ESE	641	2754	2425	636	43	0	3.21	6499	.56	2.40	2.11	.55	.03	.00	5.65
SE	681	2492	2831	1350	159	0	3.47	7513	.59	2.17	2.46	1.17	.14	.00	6.54
SSE	604	2070	3418	1576	159	5	3.71	7832	.53	1.80	2.97	1.37	.14	.00	6.81
S	636	2000	3162	1189	188	4	3.59	7179	.55	1.74	2.75	1.03	.16	.00	6.25
SSW	543	2290	2739	957	191	4	3.45	6724	.47	1.99	2.38	.83	.17	.00	5.85
SW	622	2563	2740	1190	231	12	3.54	7358	.54	2.23	2.38	1.04	.20	.01	6.40
WSW	666	2600	2827	1377	487	26	3.68	7983	.58	2.26	2.46	1.20	.42	.02	6.95
W	979	2940	3196	1310	733	59	3.38	9217	.85	2.56	2.78	1.14	.64	.05	8.02
WNW	1152	2846	3119	1834	928	91	3.30	9770	1.00	2.48	2.71	1.42	.81	.07	8.50
NW	877	2026	2102	880	382	19	3.03	6286	.76	1.76	1.83	.77	.33	.01	5.47
NNW	655	1268	972	216	41	0	2.57	3152	.57	1.10	.85	.19	.03	.00	2.74
No Direction	2800	3046	1413	580	141	37	2.06	8017	2.44	2.65	1.23	.50	.12	.03	2.00
Avg. Speed	1.21	2.96	4.87	6.70	9.09	14.11	3.19								
Tot. Entry	13924	39087	40896	16603	4130	298		114938							

Figure 3-11. C-Area Tower 1975-1979



Windrose Data

Minimum Date MMDDYY 10175
Minimum Time ZULU 0000
Entries All Classes 105815

Maximum Date MMDDYY 123179
Maximum Time ZULU 2400
Entries This Class 105815 -

Direction	Speed in Meters/Sec. ■■■■■■						Average Speed	Total Tot	Percent Time Wind & Speed ■■■■■■						Total
	0-2	2-4	4-6	6-8	8-12	> 12			0-2	2-4	4-6	6-8	8-12	> 12	
N	886	1522	600	77	30	0	2.22	3115	.84	1.44	.57	.07	.02	.00	2.94
NNE	973	2269	1100	179	28	33	2.52	4582	.92	2.14	1.04	.17	.02	.03	4.33
NE	927	3253	2630	627	71	0	3.03	7508	.88	3.07	2.49	.59	.06	.00	7.10
ENE	825	2961	2332	422	71	0	2.99	6611	.78	2.80	2.20	.40	.06	.00	6.25
E	796	2672	1669	265	39	0	2.81	5441	.75	2.53	1.58	.25	.03	.00	5.14
ESE	905	2490	1414	334	38	3	2.68	5184	.86	2.35	1.34	.32	.03	.00	4.90
SE	1389	3733	2741	842	401	24	2.91	9130	1.31	3.53	2.59	.80	.38	.02	8.63
SSE	1039	2933	2639	596	191	14	2.98	7412	.98	2.77	2.49	.56	.18	.01	7.00
S	858	2531	1457	305	132	14	2.74	5297	.81	2.39	1.38	.29	.12	.01	5.01
SSW	902	2542	1460	410	120	4	2.73	5438	.85	2.40	1.38	.39	.11	.00	5.14
SW	1072	2620	1609	452	170	13	2.69	5936	1.01	2.48	1.52	.43	.16	.01	5.61
WSW	1149	2907	1696	466	229	21	2.71	6468	1.09	2.75	1.60	.44	.22	.02	6.11
W	1124	2960	2292	941	513	16	3.03	7846	1.06	2.80	2.17	.89	.48	.01	7.41
WNW	1015	2757	2552	1037	659	48	3.19	8068	.96	2.61	2.41	.98	.62	.04	7.62
NW	868	2127	1747	674	281	6	2.93	5703	.82	2.01	1.65	.64	.27	.00	5.39
NNW	842	1896	1119	250	54	0	2.54	4161	.80	1.79	1.06	.24	.05	.00	3.93
No Direction	3047	2791	1408	497	163	9	1.89	7915	2.88	2.64	1.33	.47	.15	.00	2.94
Avg. Speed	1.21	2.91	4.78	6.73	9.18	13.12	2.73								
Tot. Entry	18617	44964	30465	8374	3190	205		105815							

Figure 3-12. D-Area Tower 1975-1979

Table 3-7. Precipitation at Savannah River Plant, 1952-1982^a

Month	Monthly precipitation (cm)		
	Maximum	Minimum	Average
Jan.	25.6	2.3	10.7
Feb.	20.3	2.4	10.9
Mar.	28.0	3.8	12.9
Apr.	21.0	1.5	8.9
May	27.9	3.4	10.8
June	27.9	3.9	11.1
July	29.4	2.3	12.5
Aug.	31.6	2.6	11.7
Sept.	22.3	1.4	10.2
Oct.	27.8	0.0	6.2
Nov.	16.5	0.5	5.9
Dec.	24.4	1.2	9.5
Annual			121.3

a. Adapted from Du Pont, 1983c.

Table 3-8. Extreme Wind Speeds for Area of Savannah River Plant^a
(meters per second)

Station	Return period	
	50-year	100-year
Greenville, S.C.	35	38
Macon, Ga.	30	31
Savannah, Ga.	35	39

a. Adapted from Simiu, Changery, and Filliben, 1979.

Thunderstorms

There is an average of 54 thunderstorm days per year at the Plant. The summer thunderstorms occur primarily during the late afternoon and evening; they can be accompanied by strong winds, heavy precipitation, or, less frequently, hail (NOAA, 1985). Summer thunderstorms are attributable primarily to convective activity resulting from solar heating of the ground and the presence of a

moist unstable maritime tropical air mass. Thunderstorm activity in the winter months is attributable mainly to frontal activity.

Tornadoes

In the Southeastern United States, most tornadoes occur in early spring and late summer, with more than 50 percent occurring from March through June. In South Carolina, the greatest percentage of tornadoes occur in April and May, about 20 percent (Pepper and Schubert, 1978) in August and September. The latter are spawned mainly by hurricanes and waterspouts. One or two tornadoes can be expected in South Carolina during April and May, and one can be expected each in March, June, July, August, and September (Purvis, 1977).

Weather Bureau records show 278 tornadoes in Georgia over the period from 1916 to 1958, and 258 in South Carolina for the period from 1950 to 1980 (Table 3-9) (Hoel, 1983). The general direction of travel of confirmed tornado tracks in Georgia and South Carolina is southwest to northeast.

Table 3-9. Tornado Occurrence by Month

Month	Georgia (1916-1958)		South Carolina (1950-1980)	
	Number	Percent	Number	Percent
Jan.	24	8.6	6	2.3
Feb.	23	8.3	14	5.4
Mar.	49	17.6	26	10.1
Apr.	93	33.5	40	15.5
May	20	7.2	53	20.5
June	14	5.0	20	7.8
July	5	1.8	17	6.6
Aug.	10	3.6	25	9.7
Sept.	8	2.9	23	8.9
Oct.	2	0.7	8	3.1
Nov.	15	5.4	11	4.3
Dec.	15	5.4	15	5.8
Total	278		258	

Occasional tornadoes are to be expected in the SRP area. Investigations of tornado damage near the Plant in 1975 and 1976 indicated wind speeds varying from 45 to 78 meters per second (Du Pont, 1980a).

Hurricanes and High Winds

Thirty-eight damaging hurricanes occurred in South Carolina during the 272 years of record (1700 to 1972); the average frequency was one storm every 7 years. These storms occurred predominantly during August and September. At

the SRP site, 160 kilometers inland, hurricane wind speeds are significantly lower than those observed along the coast. Winds of 34 meters per second were measured on the 61-meter towers only once during the history of the Plant, when Hurricane Gracie passed to the north on September 29, 1959 (Du Pont, 1982b).

Precipitation Extremes

Heavy precipitation can occur in the SRP area in association with either localized thunderstorms or hurricanes. The maximum 24-hour total was about 15.2 centimeters, which occurred during August 1964 in association with Hurricane Cleo.

Hail and Ice Storms

Hail in association with a severe thunderstorm can be expected to occur in the area about once every 2 years. Damage from such hail is rare. Ice storms caused by freezing rain can be expected about once every 4 years and are usually of short duration (Du Pont, 1982b).

3.1.7.4 Atmospheric Dispersion

Atmospheric Stability

The transport and dispersion of airborne material are direct functions of air movement. Transport direction and speed are governed by the general patterns of airflow (and by the nature of the terrain), whereas the diffusion of airborne material is governed by small-scale, random eddying of the atmosphere (i.e., turbulence). Turbulence is indicated by atmospheric stability classification. About 25 percent of the time, the atmosphere is unstable in the SRP regions; about 25 percent of the time it is neutral; and about 50 percent of the time it is stable.

Mixing Heights and Low-Level Inversions

The mixing height is the level of the atmosphere below which pollutants are easily mixed; it is often equal to the base of an elevated inversion. The depth of the mixed layer at the Plant has been measured by an acoustic sounder (Schubert, 1975). The acoustic data indicate that, as the day progresses, the mixing height rises beyond the 1000-meter range of the sounder.

An analysis of 5 years of upper-air meteorological data recorded at several stations in the SRP area (Holzworth, 1972) provides further mixing-height information. The average afternoon mixing height is about 1005 meters in the winter, 1700 meters in the spring, 1890 meters in the summer, and 1400 meters in the autumn. Mixing heights over the SRP site could be expected to be slightly lower.

Temperature inversions (air temperature increases with the height above the ground) inhibit atmospheric turbulence; hence, they are associated with small rates of atmospheric diffusion. Detailed temperature-inversion data are available from instruments on the WJBF-TV tower. The 1974 temperature measurements between 3 and 335 meters were analyzed to determine the frequency of

occurrence of several categories of temperature structure (Pendergast, 1976). About 30 percent of the time, a temperature inversion extended to or beyond the 3-to-335-meter layer. About 12 percent of the time, there was an elevated inversion with an unstable layer below; this represents the early-morning breakup of a nighttime inversion. About 9 percent of the data showed an inversion at the lower levels with an unstable layer above; this represents the transition period between an unstable daytime regime and the onset of a nighttime inversion.

Restrictive-Dilution Conditions

The dilution capacity of the atmosphere depends on local wind speed, wind-direction variability, mixing depth, and the vertical temperature profile. From 1960 to 1970, the SRP area had about 50 forecast-days of high air-pollution potential, or an average of about 5 days per year (Holzworth, 1972). Air pollution episodes are most frequent in autumn, when large anti-cyclones, which are characterized by low wind speeds, clear weather, and large-scale temperature inversions, become nearly stationary off the Atlantic coast, affecting much of the Eastern United States.

Air Quality

The States of South Carolina and Georgia have established air-quality-sampling networks. The Savannah River Plant operates an onsite sampling network. These networks monitor suspended particulates, sulfur dioxide, and nitrogen dioxide. Ambient concentrations of these pollutants near the Plant in 1984, were below local air-quality standards (Du Pont, 1985a).

Correlation of Predicted to Measured Offsite Airborne Radionuclide Concentrations

A statistical air-pollution model, XOQDOQ, uses joint-frequency data on wind speed, wind direction, and atmospheric-stability class to estimate average relative effluent concentrations, X/Q_s , and average relative deposition values, D/Q_s , at specified locations and at standard radial distances downwind. It is based on a modified Gaussian-plume equation that assumes uniform horizontal dispersion over each of 16 sectors and calculates vertical dispersion using curves fitted with polynomials (Sagendorf and Goll, 1977). The mixing height is set to 1000 meters.

Predictions of the model were compared with measurements in air of the inert radioactive gas, krypton-85, which is routinely emitted in small quantities from the SRP chemical-separations facilities. The model predictions were slightly higher than the measured values (Telegadas et al., 1980).

3.1.8 RADIATION AND RADIONUCLIDES IN THE ENVIRONMENT

3.1.8.1 Sources of Environmental Radiation

Environmental radiation consists of natural background radiation from cosmic, terrestrial, and internal body sources; medical radiation; radiation from weapons test fallout; radiation from consumer and industrial products and air travel; and radiation from nuclear facilities.

Natural radiation contributes about 48 percent of the annual dose of 195 millirem received by an average member of the population within 80 kilometers of the Savannah River Plant. Medical exposure accounts for 47 percent of the annual dose, and the combined doses from offsite weapons test fallout, consumer and industrial products, and air travel account for about 5 percent of the dose. Releases of radioactivity to the environment from the Plant account for less than 0.1 percent of the total annual dose (DOE, 1984b).

External natural radiation comes from cosmic rays and the emissions from natural radioactive ores. It is highly variable with location and altitude. Internal natural radiation arises primarily from potassium-40, carbon-14, rubidium-87, and daughters of radium-226. The widespread distribution of fertilizers and food, as well as population mobility, has an averaging effect for these long-lived radionuclides that produce the internal dose. The estimated average internal radiation exposure in the United States from natural radioactivity is 28 millirem per year (BEIR III, 1980).

Medical radiation is the largest source of exposure to manmade radiation in the United States. The average dose to an individual from medical and dental X-rays, prorated over the total population, was 78.4 millirem per year (BEIR III, 1980). (Prorating the dose over the population, as used here and in following parts of this section, is a means of arriving at an average dose that, when multiplied by the population size, produces an estimate of population exposure. It does not mean that every member of the population receives radiation exposure from these sources.) In addition, radiopharmaceuticals administered to patients for diagnostic and therapeutic purposes account for an average annual dose of 13.6 millirem when prorated over the population. The occupational exposure of 0.45 millirem per year to medical and dental personnel must be added to these patient doses. Thus, the average medical radiation dose in the U.S. population is about 92.5 millirem per year.

Fallout from nuclear weapons tests is a small source of radioactivity in the environment. The large-scale atmospheric tests conducted by the United States and the Soviet Union in 1961 and 1962 introduced radioactive materials into the stratosphere that were later distributed worldwide. A small amount of radioactivity from these tests continues to be deposited. The more recent Chinese and French tests have maintained a relatively constant rate of fallout deposition. The past and present fallout contributes to human exposure through (1) external radiation from radioactive material on the earth's surface; (2) internal radiation from inhalation of airborne fallout; and (3) internal radiation from ingestion of food and water contaminated by fallout.

Cesium-137 deposited from past nuclear weapons tests is the major source of long-lived external gamma radiation from fallout. Short-lived radionuclides also contributed significantly to external radiation for a few years after major tests but now contribute little to the dose. The current dose rate from external gamma radiation is estimated at 0.9 millirem per year (EPA, 1972).

Most doses from inhalation of fallout are received in the years immediately after exposure. However, doses from strontium-90 and plutonium-239 will be received over a lifetime because of the long residence time of these radionuclides in the body. The annual dose from inhaled fallout radioactivity was estimated at only 0.04 millirem in 1969 (EPA, 1972) and is now even lower.

Ingestion of radioactivity in food and water is the largest source of radiation exposure from fallout. The estimated dose from this source of exposure in 1980 was 3.7 millirem per year: 0.6 millirem from carbon-14, 0.4 millirem from cesium-137, and 2.7 millirem from strontium-90.

The average annual total-body dose in 1980 from fallout from nuclear weapons tests was estimated at 4.6 millirem: 0.9 from external gamma and 3.7 from ingested radioactivity.

A variety of consumer and industrial products yield ionizing radiation or radioactive materials causing radiation exposure to the general population. Some of these sources are television sets, luminous-dial watches, airport X-ray inspection systems, smoke detectors, tobacco products, fossil fuels, and building materials. The estimated total-body dose for the U.S. population from these sources is 4 to 5 millirem per year (BEIR III, 1980). About three-fourths of this dose is from external exposure to naturally occurring radionuclides in building materials.

Persons who travel by aircraft receive additional exposure from cosmic radiation; at high altitudes the atmosphere provides less shielding from this source. The average annual dose to an airline passenger is 2.8 millirem, which when prorated over the entire U.S. population amounts to an average dose of 0.5 millirem per year (BEIR III, 1980).

3.1.8.2 Environmental Radiation Levels in the Southeastern United States

The contribution of cosmic radiation to natural background dose varies with both latitude and altitude and thus will be unique to a particular location. Sea-level doses range from 30 millirem per year in Florida to 45 millirem per year in Alaska; the exposure rate increases to 200 millirem per year at an altitude of about 2400 meters (EPA, 1977). The average unshielded cosmic radiation dose in Georgia and South Carolina is 40 millirem per year (EPA, 1972).

Terrestrial gamma radiation (external to the human body) is attributed primarily to gamma-emitting radionuclides in the natural radioactive series derived from uranium and thorium, with some additional contribution from potassium-40. Variation in the distribution of these natural radioactive materials with geologic formations and their inclusion in construction materials commonly used in urban areas lead to a wide variation with location. The average unshielded external dose from this source is 60 millirem per year in Georgia and 70 millirem in South Carolina. However, the variation in these states, including the SRP area, ranges from 6 to more than 350 millirem.

Nuclear facilities in an area will also contribute to the environmental radiation level. The growth of the nuclear industry and nuclear facilities in the southeastern United States - from West Virginia to Florida and from Arkansas to South Carolina - has been rapid, most of it occurring in the 1970s. In this region, 24 power reactors were either operating or licensed to operate in 1981. Another 34 power reactors were under construction and 4 reactors were being planned. When all of these are operating, there will be 62 power reactors in the southeastern United States. Typically, the average radiation dose to individuals within 80 kilometers of a nuclear facility is quite low.

Data on releases from 46 nuclear powerplants operating in 1979 indicate that the average radiation dose within 80 kilometers of a plant was 0.025 millirem (NRC, 1982).

An airborne radiological survey of the Savannah River coastal region was performed in 1975 to establish terrestrial dose equivalent rates (Hayes, 1977). These rates varied from about 0.001 millirem per hour over water to 0.009 millirem per hour at one location on Wassaw Island. In general, the higher rates occurred over beaches, where heavy minerals containing natural thorium and uranium occur. Excluding the water areas, the terrestrial rate averages about 0.003 millirem per hour in this area, which is comparable to other Coastal Plain rates of 0.002 to 0.003 millirem per hour and is about one-half that measured for the Plant. The average dose equivalent rate for the Savannah River marine area is about the same as that measured in Galveston, Texas, and Cape Canaveral, Florida, and somewhat less than that in the Los Angeles, California, area. One radiation anomaly defined in this survey was noted on Hutchinson Island, Florida, where dredge spoils have been deposited. The cesium-137 concentration of the post-1957 dredge soil sediment ranges from about 0.3 to 2.7 picocuries per gram. About half the cesium-137 in the post-1957 sediment can be attributed to fallout from weapons testing (Marter, 1974).

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3.1.8.3 Environmental Radiation Levels in the Vicinity of the Savannah River Plant

A summary of the major sources of exposure for the population within 80 kilometers of the Plant and for the river-water-consuming population in Beaufort and Jasper Counties, South Carolina, and in Port Wentworth, Georgia, is presented in Table 3-10. Many of the factors such as the internal radionuclide dose and the medical dose are independent of the site. The factors that are site-dependent are discussed below.

The Savannah River Plant and the surrounding area lie between latitudes 33°N and 34°N, with an altitude variation between sea level and roughly 100 meters. The estimated total unshielded dose equivalent from cosmic radiation in the vicinity of the Plant within an 80-kilometer radius is 35 millirem per year, of which 29 millirem per year are from the ionizing component and 6 millirem per year are from neutrons (Langley and Marter, 1973). Shielding by buildings and the body reduces the cosmic radiation dose to about 32 millirem per year - a 10-percent reduction.

Within 80 kilometers of the Plant, measured external gamma dose rates range from 6 millirem to 385 millirem per year (Dukes, 1984). A value of 55 millirem per year represents the average unshielded external terrestrial background in the vicinity of the Plant. Shielding by buildings and the body reduces this terrestrial radiation dose to about 33 millirem per year - a 40-percent reduction.

Atmospheric testing caused 25,600,000 curies of cesium-137 to be deposited on the earth's surface (United Nations, 1977). About 104 millicuries of cesium-137 per square kilometer were deposited in the latitude band 30°N to 40°N, where South Carolina is located. The total deposition was 2850 curies in the 27,400 square kilometers of the Savannah River watershed and 80 curies of cesium-137 in the 780 square kilometers of the Plant. The deposited cesium-137 became attached to soil particles and has undergone only slow transport

Table 3-10. Major Sources of Radiation Exposure in the Vicinity of the Savannah River Plant

Source of exposure	Dose to average individual (mrem/yr)	Percent of exposure
Natural background radiation		
Cosmic radiation	32.0	
External terrestrial gamma	33.0	
Internal	<u>28.0</u>	
Total	93.0	47.6
Medical radiation		
Diagnostic X-rays	78.4	
Radiopharmaceuticals	13.6	
Medical and dental personnel	<u>0.5</u>	
Total	92.5	47.3
Weapons test fallout	4.6	2.4
Consumer and industrial products	4.5	2.3
Air travel	0.5	0.3
Nuclear facilities (other than SRP)	0.1	0.1
Savannah River Plant environmental radioactivity (1980)	<u>0.2</u>	0.1
Grand total	195.4	

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from the watershed. Results from routine SRP Health Protection Department monitoring programs indicate that since 1963 about 1 percent of the 2850 curies of cesium-137 deposited on the total Savannah River watershed has been transported down the river (Hayes, 1983).

Onsite monitoring conducted by the SRP Health Protection Department from 1976 to 1982 shows that an average of 50 millicuries per square kilometer of cesium-137 were in the upper 5 centimeters of the soil column within an 80-kilometer radius (Du Pont, 1983a). This value is one-half the amount originally deposited from worldwide fallout and implies that some of the radiocesium has undergone hydrologic transport to the Savannah River.

SRP monitoring in the Savannah River shows that the concentration of radio-cesium in river water has been very low in the past several years. From 1979 through 1982, the mean concentration of cesium-137 at the U.S. Highway 301 bridge was 0.08 picocurie per liter and was near the limit of detection at the

control station upriver of the Plant (Du Pont, 1980b, 1981, 1982c, 1983a). For the second quarter of 1983, measurements of the radiocesium in the potable water at the North Augusta, Beaufort-Jasper, and Cherokee Hill water-treatment plants averaged 0.006, 0.028, and 0.033 picocurie per liter, respectively, or less than 0.017 percent of the EPA drinking water standard of 200 picocuries per liter (Kantelo and Milhom, 1983).

Turbulence in the Savannah River generally keeps fine soil particles in suspension. These particles are deposited where the river velocity and turbulence are low, such as inside river bends, downstream from obstructions, in oxbow lakes, and on the floodplain, and where flocculation occurs in the estuary below River Mile 40. Riverbed sediments upstream from the Plant normally have about 1 picocurie per gram or less of radiocesium (Du Pont, 1982b).

In 1974, riverbed sediments downstream of the Plant had concentrations of radiocesium of about 2 picocuries per gram near the U.S. Highway 301 bridge and 6.5 picocuries per gram at the South Carolina Highway 119 bridge near Clyo, Georgia (Du Pont, 1982b). Studies performed in 1978 showed that the radiocesium concentrations were about 0.6 picocurie per gram at the control station above the Plant and less than 0.8 picocurie per gram at sampling stations between Little Hell Landing and the Highway 301 bridge (Du Pont, 1982b).

In 1983 the tritium concentrations in the potable water produced by the Beaufort-Jasper and Cherokee Hill water-treatment plants averaged 2100 and 2800 picocuries per liter, respectively, or less than 14 percent of the EPA drinking water standard of 20 picocuries per milliliter; very low concentrations of cobalt-60, strontium-89 and -90, iodine-129, uranium, and plutonium-239 were also measured in the water produced by these plants (Du Pont, 1984).

Whole-body bioaccumulation factors - the ratio of cesium-137 concentrations in fish and cesium-137 concentrations in water - for fish taken from the Savannah River at the U.S. Highway 301 bridge from 1965 to 1970 average about 2300. The mean bioaccumulation factor for 20 species of fish (527 specimens) from Steel Creek was found to be 2019 whole-body and 3029 flesh (Smith et al., 1982; Ribble and Smith, 1983).

The radiation dose to a hypothetical individual on the Plant boundary from 1984 SRP atmospheric releases of radioactive materials was 2.4 millirem maximum and 0.87 millirem average. The average dose from SRP atmospheric releases to persons living within 80 kilometers of the Plant was 0.2 millirem per year. The maximum radiation doses to an individual downriver of the Plant who consumed Savannah River water were 0.2 millirem (adult) at the Cherokee Hill water treatment plant at Port Wentworth, Georgia, (near Savannah) and 0.18 millirem (child) at the Beaufort-Jasper County water treatment plant near Beaufort, South Carolina (Du Pont, 1985a).

The only other nuclear facility within 80 kilometers that has been operational during the operating history of the Savannah River Plant is a low-level-waste burial site operated by Chem-Nuclear Systems, Inc., near the eastern boundary of the Plant. This facility, which started operation in 1971, releases essentially no radioactivity to the environment (Chem-Nuclear Systems, Inc., 1980), and the population dose from normal operations is negligible. Plant Vogtle's

unit 1 began commercial operations on June 1, 1987; therefore, background radiation levels will be evaluated as the data becomes available.

The Plant has monitored onsite streams since the early 1950s. Water quality monitoring in onsite streams shows that radioactive releases prior to entry into the Savannah River are well within DOE concentration guidelines established for releases to uncontrolled areas (Ashley and Zeigler, 1981; Ashley, Zeigler, and Culp, 1982; Ashley et al., 1982; Du Pont, 1985b).

Appendix D contains additional information on radiocesium and tritium in the SRP environment.

3.2 PEN BRANCH AND INDIAN GRAVE BRANCH (K-REACTOR)

3.2.1 GEOGRAPHY

Pen Branch follows a path roughly parallel to Four Mile Creek until it enters the Savannah River swamp (Figure 3-2). The only significant tributary to Pen Branch is Indian Grave Branch, which flows into Pen Branch about 8 kilometers upstream from the swamp. Pen Branch enters the swamp about 5 kilometers from the river, flows directly toward the river for about 2.4 kilometers, and then turns and runs parallel to the river for about 8 kilometers before joining with Steel Creek about 0.8 kilometer from its mouth at the river.

Pen Branch and Indian Grave Branch drain about 56 square kilometers of watershed upstream from the swamp. Indian Grave Branch receives the cooling water from K-Reactor. Upstream from K-Area discharges, the flow of Indian Grave Branch averages about 0.03 cubic meter per second and that of Pen Branch 0.1 to 0.3 cubic meter per second.

3.2.2 HISTORIC AND ARCHAEOLOGICAL RESOURCES

The most recent archaeological and historic resources survey of the Pen Branch watershed area, which includes Indian Grave Branch, was conducted from May through August 1984. Forty sites were located in the watershed during this survey (see Figure E-1 in Appendix E). Of the sites found in the Pen Branch area, none is in an area that could be affected by the proposed cooling-tower alternatives for K-Reactor.

3.2.3 HYDROLOGY

Since November 1976, a USGS flow recorder has been maintained at SRP Road A-13.2 on Pen Branch. From 1976 to 1982, the flow at this station ranged from a minimum of 0.6 cubic meter per second when K-Reactor was not operating to a maximum of 26.9 cubic meters per second during simultaneous K-Reactor operation and heavy precipitation. During water year 1982, the mean flow rate at this station was 10.8 cubic meters per second.

Before 1951, Pen Branch was a small, single-channel meandering creek flowing through a broad, heavily vegetated floodplain. K-Reactor effluent changed the creek to a wide, multichannel, braided stream system flowing within denuded floodplains (Ruby, Rinehart, and Reel, 1981). Severe erosion straightened, widened, and deepened sections of the stream channel immediately below the

reactor discharge point. Further downstream, multiple channels formed across the floodplain to accommodate the increased flow and sediment load. A combination of thermal stress, flooding, and root disturbance caused extensive vegetative loss around the creek. Deltas accreted at the stream mouth where a substantial volume of the eroded material was deposited. Deposition was initially rapid, and then gradually tapered off as the drainage system increased in size. Present deposition rates are slow, and minor recolonization of thermally resistant vegetation has begun (Ruby, Rinehart, and Reel, 1981).

Data collected under the recent intensive water quality study initiated in July 1983 suggest that input of large flows (11 cubic meters per second) of Savannah River water at high temperatures (40°-70°C) has the most pronounced effect on the water quality of Pen Branch. Concentrations of nutrients, cations, and metals in the thermal portion of Pen Branch reflect those of its source water, the Savannah River (Du Pont, 1985b). Table 3-11 provides a comparison of selected water-quality parameters from sampling points upstream and downstream of K-Reactor discharges.

3.2.4 ECOLOGY

3.2.4.1 Terrestrial Ecology

Indian Grave Branch/Pen Branch have about 1730 acres of wetlands upstream of the swamp. Emergent marsh (115 acres) and open water (145 acres) are common below the K-Reactor discharge point. Some hardwoods exist on the outer perimeter of the thermally affected areas (326 acres), but most occur in non-thermal tributaries (338 acres) or upstream of the K-Reactor discharge (724 acres). K-Reactor cooling water releases have altered more than 38 percent (670 acres) of the Indian Grave Branch/Pen Branch forested wetlands (Du Pont, 1985b). The star-nosed mole, marsh rabbit, beaver, muskrat, rice rat, river otter, and mink are mammals commonly associated with wetland/floodplain habitats. Studies indicate that none of these mammals inhabit reactor effluent streams on the Savannah River Plant during periods of elevated water temperatures. Beaver and otter, however, have been found to reoccupy these streams within 24 hours of reactor shutdown (Du Pont, 1985b).

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The Savannah River Swamp System is used extensively by waterfowl, particularly during the fall and winter months when these areas provide foraging habitat for migratory species. Based on roost counts, 1200 wood ducks and mallards wintered (1983-1984) in the Steel Creek delta and associated areas. Waterfowl use of the swamp normally is associated with open areas with sparse vegetation caused by increased flows and heated effluent. Of the 12 waterfowl species, researchers have performed the most thorough studies of the foraging ecology of the wood duck, followed by that of the mallard. Most of the swamp (thermal, post-thermal, and nonthermal) was used by migrating wood ducks from October through March.

TE

Approximately 22 species of amphibians and reptiles reside in the natural (i.e., nonthermal) streams and swamps of the Savannah River Plant. All of these species have also been reported in the post-thermal areas of Steel Creek (Du Pont, 1985b).

TE

No amphibians or reptiles are known to persist on a routine basis in areas of severe thermal alteration, although some species of frogs live in aquatic

TE

Table 3-11. Pen Branch and Indian Grave Branch Water Quality:
November 1983 to May 1984^a

Parameter, mean concentration (mg/l ^b)	Pen Branch upstream of K-Reactor at Road B	Indian Grave Branch downstream of K-Reactor	Pen Branch downstream of K-Reactor at Road A-13
Temperature (°C)	12.4	57.6 ^c	49.8 ^c
Dissolved oxygen	8.4	5.7	5.9
pH (units) (range)	5.3-8.5	5.9-8.7	5.6-8.1
Total suspended solids	10.5	11.7	25.1
Chloride	2.3	5.2	5.1
Phosphorus, total	0.029	0.078	0.083
Nitrate-nitrogen	0.035	0.289	0.266
Calcium, total	3.7	3.0	2.8
Aluminum, total	0.57	1.35	1.58
Sodium, total	1.7	5.3	5.5
Iron, total	0.54	1.06	1.22

a. Adapted from Du Pont, 1985b.

b. Except as noted.

c. During reactor operations; other tabulated values represent measurements made during reactor operations and during periods of reactor shutdown.

habitats that experience elevated temperatures, and some have deposited eggs in aquatic sites where extreme temperatures occurred. Frogs and toads exhibit life history changes under elevated thermal conditions, particularly as tadpoles, by developing and metamorphosing more rapidly and at smaller sizes than larvae developing under normal temperature conditions (Du Pont, 1985b).

TE The slider is the most prevalent turtle on the Plant. This species apparently thrives in areas of moderately elevated water temperatures; here they have faster growth rates and attain larger body sizes than turtles from local natural habitats. These changes can be attributed to improved diet quality, a longer growing season, and more rapid ingestion rates (Du Pont, 1985b).

A few other reptile species, primarily water snakes and turtles, might also occur in thermally affected areas, but not in numbers characteristic of ambient-temperature streams in the region (Du Pont, 1985b).

3.2.4.2 Aquatic Ecology

Aquatic Flora

The substrate from the upper reaches of Pen Branch is primarily sand and silt, with interspersions of leaf packs, woody debris, macrophytes and algae, and isolated gravel beds (Du Pont, 1985b). Blue-green algal mats similar to those in Four Mile Creek cover the substrate. Riparian vegetation includes sedges, grasses, wax myrtle, and buttonbush, while duckweed is abundant in the many side pools and channels.

The delta region of Pen Branch is characterized by an open and closed canopy of living and dead bald cypress and tupelo. Many channels braid through the area in a shallow sheet flow. Dominant vegetation consists of smartweed, arrowhead, creeping burhead, water primrose, sedges, and duckweed. Closed canopy areas at the delta support fewer emergent plants.

TE

Aquatic Fauna

Between November 1983 and May 1984, studies for the Comprehensive Cooling-Water Study sampled macroinvertebrates from one station in the main Pen Branch channel and two stations in the Pen Branch delta (Du Pont, 1985b; Appendix C). The main channel of Pen Branch is dominated by (in decreasing abundance) segmented worms (Oligochaeta), midges (Diptera), roundworms (Nematoda), and snails (Gastropoda). Also present were mayflies (Ephemeroptera), caddisflies (Trichoptera), beetles (Coleoptera), scuds (Amphipoda), and mites (Hydracarina).

Nearly twice as many taxa occurred in the delta area than in the main channel. In the delta, sites with a closed canopy exhibited a higher average density (Du Pont, 1985b; Appendix C). Species composition was very similar to that of the main Pen Branch channel (i.e., midges, segmented worms, roundworms, and mayflies dominate).

The dominant adult fish in the nonthermal upper reaches of Pen Branch are sunfish, bullheads, and chubsuckers. Most of these species are benthic in habitat or are found near instream woody structures. Fish species generally associated with fast-flowing waters (i.e., darters) are absent. The thermal reaches of Pen Branch are dominated by shiners, sunfish, madtoms, and darters.

Ichthyoplankton abundance in Pen Branch is very low, ranging from zero to greater than 50 per 1000 cubic meters (Du Pont, 1985b; Appendix C). Among the ichthyoplankton, the dominant species was the mosquitofish, which is more tolerant of high temperatures. The few ichthyoplankters present probably drifted into the main channel from adjacent cooler refuge areas. The area above the reactor discharge is populated by minnows and darters in very low abundance.

3.2.5 RADIOACTIVITY RELEASES AND RADIOLOGICAL TRANSPORT

Approximately 16.2 curies of cesium-137 (decay corrected to 1980) have been released to Pen Branch from the K-Reactor area (Lower and Hayes, 1984), where the creek (Indian Grave Branch) receives a cooling water discharge of about 11.3 cubic meters per second. Sediment samples 8 centimeters in depth obtained from the Pen Branch delta-swamp system below Road A-13.2 typically exhibit cesium-137 concentration less than 1.5 picocuries per gram (Du Pont, 1985b). Table 3-12 lists radionuclide concentrations in water and aerial radiological survey results for Pen Branch and Indian Grave Branch. After receipt of cesium-137 from both Pen Branch and Steel Creek (DOE, 1984b), the sediments at the mouth of Steel Creek exhibit average concentrations of 16.7 picocuries per gram.

Approximately 357,600 curies of tritium were released to Pen Branch from the K-Reactor area through 1980. Approximately 41 percent of this tritium was

Table 3-12. Radionuclide Concentrations in Water and Sediment and Aerial Radiological Survey Results for Pen Branch and Indian Grave Branch (K-Reactor)

Location	^a Water (pCi/l)		^b Sediment (pCi/gm)	^c Aerial Survey (R/hr)	
	Cs-134, Cs-137	H-3	Cs-137	Cs-137 (min)	Cs-137 (max)
Road A	1.63	34,700	(d)	-	1.2
Road A ^e	1.52	32,000	(d)	NA ^f	NA
Delta	(d)	(d)	4.7	-	1.2
Steel Creek-Pen Branch Mouth	(d)	(d)	16.7	(d)	(d)

a. Three-year-mean concentration unless otherwise noted. Sources: Ashley and Zeigler, 1981; Ashley et al., 1982; Ashley, Zeigler, and Culp, 1982.

b. Five-year-mean concentration (1977-1981). Source: Lower, 1984.

c. 1979 survey. Source: Boyns and Smith, 1982.

d. No data available.

e. 1984 data only. Source: Du Pont, 1985b.

f. NA = Not available.

from the K-Area containment basin migration (Du Pont, 1985b). Released tritium, which remains soluble in Pen Branch and Indian Grave Branch, is released to the Savannah River via Steel Creek. Tritium concentrations and river flow are measured routinely at U.S. Highway 301.

3.3 FOUR MILE CREEK (C-REACTOR)

3.3.1 GEOGRAPHY

Four Mile Creek follows a generally southwesterly path to the Savannah River for a distance of about 24 kilometers (Figure 3-2). In the Savannah River swamp along the river, part of the creek flow empties into Beaver Dam Creek. The remainder discharges through an opening in the levee between the swamp and the river, seeps through the levee into the river, or moves through the swamp and mixes with the flows from Steel Creek and Pen Branch (Du Pont, 1985b).

Four Mile Creek and Beaver Dam Creek together drain about 90 square kilometers. Reactor cooling water from C-Area is discharged to Four Mile Creek. After the junction with the C-Reactor cooling water, the creek flows about 11 kilometers before entering the Savannah River swamp (Du Pont, 1985b).

3.3.2 HISTORIC AND ARCHAEOLOGICAL RESOURCES

The most recent archaeological and historic resources survey of the Four Mile Creek watershed area was conducted from May through August 1984. A total of 25 sites was located in the watershed during this survey (see Figure E-1 in Appendix E). Only one site (38BR548) in the Four Mile Creek survey area could be affected by the proposed cooling-tower alternatives for C-Reactor. Site 38BR548 is a small prehistoric lithic and ceramic scatter located on a terrace edge adjacent to the bank of the northern branch of Four Mile Creek. No further work has been recommended for this site, because the potential yield of additional research information is negligible.

3.3.3 HYDROLOGY

The average flow upstream of any SRP discharge to Four Mile Creek is about 0.015 cubic meter per second, which is increased by SRP discharges and drainage to about 0.6 cubic meter per second just upstream from the confluence with the C-Reactor discharges. After the junction with the C-Reactor cooling water discharge, the creek flows about 11 kilometers before entering the river swamp at flow rates exceeding 11 cubic meters per second during periods of C-Reactor operation (Lower, 1985).

Prior to 1951, Four Mile Creek was a small, single-channel, meandering creek flowing through broad, heavily vegetated floodplains. C-Reactor discharges changed the creek to a wide, multichannel, braided stream system flowing within denuded floodplains (Ruby, Rinehart, and Reel, 1981). Severe erosion straightened, widened, and deepened sections of the stream channel immediately below the reactor discharge point. Further downstream, multiple channels formed across the floodplain to accommodate the increased flow and sediment load. A combination of thermal stress, flooding, and root disturbance caused extensive vegetative loss in a zone around the creek. Deltas accreted at the stream mouth, where much of the substantial volume of eroded material was

deposited. The initial rapid progression of deposition gradually tapered off as the drainage system increased in size. Present deposition rates are slow, and minor recolonization of thermally resistant vegetation has begun (Ruby, Rinehart, and Reel, 1981).

Table 3-13 provides a comparison of temperature and dissolved oxygen data from sampling stations above and below C-Reactor discharges (Du Pont, 1985b).

Table 3-13. Temperature and Dissolved Oxygen in Four Mile Creek^a

Location	Mean temperature (°C)	Mean dissolved oxygen (mg/l)
Four Mile Creek upstream of C-Reactor	16.0	7.6
Four Mile Creek downstream of C-Reactor at Road A	38.5	6.6

a. Source: Adapted from Jacobsen et al., 1972; Du Pont, 1985b.

In relation to upstream concentrations from the Four Mile Creek Road A-7 site, concentrations of sulfates, aluminum, calcium, and sodium were slightly to significantly reduced at the mouth of Four Mile Creek (Table 3-14). Some buffering might have occurred in the onsite swamp for the Four Mile Creek flow prior to the river confluence; however, concentrations of chlorides and total iron were unchanged or were increased (Du Pont, 1985b).

3.3.4 ECOLOGY

3.3.4.1 Terrestrial Ecology

The Four Mile Creek floodplain has approximately 1900 acres of wetlands, which are principally (72 percent) bottomland hardwoods. Downstream of the C-Reactor outfall, open water and emergent marsh near the stream have replaced the original hardwood community. Away from the thermally affected areas in the floodplain, hardwoods occupy 445 acres. Overall, approximately 60 percent (1147 acres) of the Four Mile Creek wetlands have been impacted by C-Reactor discharges (Du Pont, 1985b).

Waterfowl use of Four Mile Creek is associated primarily with the delta area where Four Mile Creek empties into the Savannah River swamp. A census of this system and the stream deltas was taken by aerial surveys weekly from November 1 to April 1, from 1981 to 1983. In addition, ground counts were conducted between October and March, 1981 to 1984 (Du Pont, 1985b).

Table 3-14. Four Mile Creek Water Quality^a

Parameter, mean concentration (mg/l) ^b	Four Mile Creek upstream of C-Reactor at Road A-7	Four Mile Creek downstream of C-Reactor at the mouth
pH (units) (range)	5.0-7.6	5.7-7.9
Chlorides	3.3	4.84
Sulfates	5.94	5.45
Aluminum	0.53	0.43
Calcium	3.40	2.00
Sodium	10.8	6.32
Iron, total	0.29	0.33
Mercury, total	0.001	0.002

a. Source: Adapted from Du Pont, 1985b.

b. Except as noted.

No self-sustaining reproducing populations of the American alligator have been observed in Four Mile Creek or its delta (Du Pont, 1985b). Wood storks were observed feeding in the Four Mile Creek swamp area in 1984 but not in 1983 (Coulter, 1986).

3.3.4.2 Aquatic Ecology

Aquatic Flora

Four Mile Creek is a relatively deep (0.3- to 1.5-meter), fast-flowing (about 140 centimeters per second) stream above its confluence with the Savannah River swamp. In this area the flora is sparse, reflecting the influence of high flow and elevated (greater than 40°C) water temperatures. The substrate is primarily sand, organic matter, silt, and clay. In backwaters and shallow areas, particularly on clay outcrops, thick mats of bluegreen algae cover the bottom. Tag alder and wax myrtle dominate the riparian vegetation. Further downstream toward the swamp, the stream is braided over a marsh-like area where a few standing dead bald cypress remain. In this area, defined and deeper channels are relatively free of vegetation, but there are thick growths of sedges on the banks. Thick mats of blue-green algae cover the shallower areas. Deeper substrates (mainly sand) are void of vegetation (Du Pont, 1985b).

Aquatic Fauna

Studies conducted for the Comprehensive Cooling-Water Study sampled macro-invertebrates from the lower and middle reaches of Four Mile Creek between November 1983 and May 1984. In addition, samples were collected from the mouth of Four Mile Creek from September 1982 through August 1983 (Du Pont, 1985b; Appendix C).

Four Mile Creek had the fewest taxa (16 to 29) and nearly the lowest density considering all sampling methods (natural and artificial substrates) of all

SRP streams sampled, including the thermally disturbed sites (Du Pont, 1985b; Appendix C). The macroinvertebrates were dominated by nematode roundworms (Nematoda), segmented worms (Oligochaeta), and midges (Diptera). Also collected - in decreasing order of abundance - were caddisflies (Trichoptera), mayflies (Ephemeroptera), snails (Gastropoda), springtails (Collembola), and scuds (Amphipoda).

Many aquatic studies have been conducted during the past 34 years on the Savannah River Plant; however, the most intensive study (the Comprehensive Cooling-Water Study) of the fish community of the SRP streams and the Savannah River began in 1983 (Du Pont, 1985b). Appendix C summarizes the results of this investigation and presents additional pertinent data.

Creek flows and reactor effluent discharge temperatures influence the relative abundance, species composition, and seasonal occurrence of adult fish in Four Mile Creek. Adult fish are most abundant in the mouth of the creek during the winter (December through February), when C-Reactor is operating. Fish avoid this region during periods of excessively high water temperatures (greater than 40°C), which usually occur from May to October.

Upper Four Mile Creek was sampled between Road A and the swamp during a 50-day reactor shutdown in early 1984. Mosquitofish accounted for more than 97 percent of the fish collected at the three sites; other species collected included bowfin, sunfish, mudminnows, shiner, and pickerel. A more diverse assemblage of fish was collected from the lower Four Mile Creek station between the delta and the Savannah River. Gizzard shad (42 percent) and largemouth bass (14 percent) dominated the catch; mosquitofish comprised only 2 percent. The low abundance and low species diversity at both stations is related to the extremely low habitat diversity in Four Mile Creek.

The Comprehensive Cooling Water Study (Du Pont, 1985b) included a sampling program to characterize the adult fish community of SRP streams for fish spawning. Researchers collected ichthyoplankton samples weekly at six locations in Four Mile Creek; they collected 203 ichthyoplankters between March 14 and June 3, 1984. The dominant taxa were sunfish or bass (32 percent) and the brook silverside (14 percent). Other taxa present were shad, crappie, yellow perch, darters, minnows, and carp (Appendix C). Because C-Reactor was not operating during most of March 1984, mean temperatures were only 5° to 10°C above Savannah River temperatures. During this time, ichthyoplankton were absent from the middle and upper reaches of the creek, but were found in low densities in the creek mouth and swamp. During C-Reactor operation, creek temperatures ranged from 30° to 50°C; as expected, few ichthyoplankters were present. Brook silversides and other unidentifiable eggs and larvae collected during C-Reactor operations from the middle and upper reaches might have drifted into the channel from adjacent refuge areas (Appendix C).

Ichthyoplankton abundance in Four Mile Creek and the associated swamp appear to be strongly influenced by water levels in the Savannah River (Du Pont, 1985b; Appendix C). High river flows probably transport ichthyoplankton into thermally impacted portions of the swamp from adjacent unimpacted areas. In addition, some fish might use thermally impacted areas for spawning during high river flows because flow patterns for the heated water are altered dramatically during such periods.

3.3.5 RADIOACTIVITY RELEASES AND RADIONUCLIDE TRANSPORT

Approximately 53.4 curies of cesium-137 (decay corrected to 1980) have been released to Four Mile Creek. Of this total, about 31.5 curies were released to the creek from the F- and H-Areas, where the stream flow averages less than 0.5 cubic meter per second (Lower, 1984; Lower and Hayes, 1984). The remainder (21.9 curies) was released from the C-Reactor area, where the cooling water discharge to the creek is about 11 cubic meters per second. Creek sediments at SRP Road A-7 (above the confluence of Four Mile Creek and the C-Reactor cooling water discharge) exhibit average cesium-137 concentrations of 37.5 picocuries per gram, some four times the average concentration in the delta area. Table 3-15 lists radionuclide concentrations in water, sediments, and aerial survey results for Four Mile Creek.

Released tritium remains soluble in Four Mile Creek. Tritium concentrations and river flow are measured routinely at U.S. Highway 301. Comparisons of the amount of tritium released from SRP facilities with the amount of tritium measured in transport in the Savannah River have continued to show excellent agreement (about 97 percent in 1983) (Lower and Hayes, 1984).

Approximately 388,600 curies of tritium were released to Four Mile Creek through 1980. Of this total, about 139,200 curies were released to the creek from the F- and H-Areas. The remainder (249,400 curies) were released from the C-Reactor area (Du Pont, 1985b). Approximately 99 percent of the F- and H-Area tritium was from seepage-basin migration.

3.4 BEAVER DAM CREEK (D-AREA COAL-FIRED POWERHOUSE)

3.4.1 GEOGRAPHY

Beaver Dam Creek is located 1.6 to 3.2 kilometers west of Four Mile Creek; it flows in a southwesterly direction from the 400-D Area through the Savannah River swamp to the Savannah River (Figure 3-2). Beaver Dam Creek is the receiving stream for the cooling water effluent from the coal-fired powerhouse in the D-Area.

Since June 1974, a flow recorder located 1.6 kilometers downstream from D-Area in Beaver Dam Creek has recorded an average discharge of about 2.4 cubic meters per second during D-Area operation.

3.4.2 HISTORIC AND ARCHAEOLOGICAL RESOURCES

Intensive archaeological and historic resources surveys of the Beaver Dam Creek floodplain area and the area west of the creek in D-Area were conducted during October and November of 1985. Only one site, 38BR450, was located in the watershed during these surveys (see Figure E-1 in Appendix E). Site 38BR450 is considered a significant archaeological resource and has been recommended for eligibility for nomination to the National Register of Historic Places.

AT-1
AT-2
AZ-1

Table 3-15. Radionuclide Concentrations in Water and Sediment and Aerial Radiological Survey Results for Four Mile Creek (C-Reactor)

Location	Water (pCi/l) ^a		Sediment (pCi/gm) ^b	Aerial Survey (R/hr) ^c	
	Cs-134, Cs-137	H-3	Cs-137	Cs-137 (min)	Cs-137 (max)
Opposite F- and H-Areas	e	e	e	1.2	38.1
Road A-7 ^f	e	800,000	18.0	NA	NA
Below F-Area to Road 3	e	e	e	1.2	19.0
Road A	2.08	70,500 ^d	37.5	-	1.2
Road A ^f	2.05	61,000	e	NA ^g	NA
Delta	e	e	8.6	1.2	4.8

a. Three-year-mean concentration unless otherwise noted. Sources: Ashley and Zeigler, 1981; Ashley et al., 1982; Ashley, Zeigler, and Culp, 1982.

b. Five-year-mean concentration (1977-1981). Source: Lower, 1984.

c. 1979 Survey. Source: Boyns and Smith, 1982.

d. 1980 and 1981 data only.

e. No data available.

f. 1984 data only. Source: Du Pont, 1985b.

g. NA = Not available.

3.4.3 HYDROLOGY

Since placement of the heavy-water plant on standby status in 1982, the only direct thermal input to Beaver Dam Creek has been that resulting from the powerhouse operations. Thermal effluent also enters the lower portion of Beaver Dam Creek via Four Mile Creek, which receives C-Reactor discharges. The water from Beaver Dam Creek mixes with part of the flow from Four Mile Creek in the onsite swamp before it is discharged to the Savannah River through the mouth of Beaver Dam Creek (Jacobsen et al., 1972). Data from the water quality station at the mouth of Beaver Dam Creek thus reflects inputs from both streams (Du Pont, 1985b). At this station, the flow inputs from Beaver Dam Creek and Four Mile Creek are approximately equal (Du Pont, 1982b).

The water quality station located in Beaver Dam Creek upstream from the onsite swamp is the only station monitored routinely in a thermally impacted zone. From 1973 to 1982, Beaver Dam Creek received heated effluents from both the powerhouse and the heavy-water production facilities. Since June 1974, flows in the creek have ranged from about 1.2 to 5.6 cubic meters per second (Du Pont, 1985b). With the exception of temperature criteria, all other water classification requirements for Class B streams (see Section 3.1.5.1.2) were met at this station. Water quality data for selected parameters are provided in Table 3-16.

3.4.4 ECOLOGY

3.4.4.1 Terrestrial Ecology

Before the Savannah River Plant began operations, Beaver Dam Creek was probably an intermittent stream. During the construction of facilities in D-Area, a canal was built to carry cooling water to the creek, which discharges after 1700 meters to the Savannah River swamp. A narrow band of bottomland hardwood and scrub-shrub forest borders the stream from the D-Area process-water outfall to the swamp (Du Pont, 1985b).

Current D-Area powerhouse thermal discharges, combined with the slow-flowing backwaters along the creek, have provided habitat for a dense population of alligators. A minimum of 28 alligators representing multiple size classes (equivalent to age classes) longer than 1 meter inhabit this stream (based on aerial surveys from December 1983 to March 1984). Subsequent ground surveys in April and May 1984 resulted in the capture of 11 alligators representing age classes of 1-, 2-, and 3-year-olds. With the exception of one 3-year-old, the other 10 alligators were probably not large enough to have been observed during the aerial surveys. The backwater areas along the creek provide excellent breeding and nesting habitat; they probably support a self-sustaining alligator population, because both adult and juvenile sizes have been observed (Du Pont, 1985b).

In 1983 between 306 and 363 wood storks were observed onsite from June 21 to September 29 (Smith et al., 1983; Coulter, 1986). There were a total of 15 group sightings during 35 observation days, with 80 percent of the sightings occurring on Beaver Dam Creek (7 sightings) and Steel Creek (5 sightings) (Coulter, 1986). The 12 sightings that were made on the two creeks accounted for more than 90 percent of the total members of wood storks observed on the site (Coulter, 1986).

Table 3-16. Beaver Dam Creek Water Quality Downstream of All 400-D Area Effluents (November 1983-May 1984)^a

Parameters	Mean concentration (mg/l ^b)
Temperature (°C)	21.9
Dissolved oxygen	7.5
pH (units) (range)	6.4-7.6
Chlorides	5.8
Nitrate + nitrite (as N)	0.24
Iron, total	1.16
Total alkalinity (as CaCO ₃)	13.2
Phosphorus, total	0.078
Calcium, total	3.0
Aluminum, total	1.51
Sodium, total	5.6
Suspended solids	46.4

a. Adapted from Du Pont, 1985b.

b. Except as noted.

In 1984, more than 370 wood storks were observed on the Plant from May 20 to November 16. There were a total of 59 group sightings during 89 observation days, with more than 54 percent of the sightings occurring on Beaver Dam Creek and Steel Creek (Coulter, 1986). Use of Four Mile Creek was documented in 1984 for the first time and accounted for 22 percent of the group sightings (Coulter, 1986). The 32 sightings that were made on Beaver Dam Creek (19 sightings) and Steel Creek (13 sightings) accounted for 54 percent of the total number of wood storks observed on the Plant (Coulter, 1986).

Apparently wood storks were more widely dispersed over the site in 1984 than 1983. However, some of the variability may be explained by an increased effectiveness of observers in locating birds, a more intensive survey, and a survey of longer duration.

Estimates of prey density and biomass from the 1984 and 1983 Steel Creek sites were highly variable. Generally, however, there was a higher density and biomass of prey in 1984. No prey density or biomass data were collected on Beaver Dam Creek (Coulter, 1986).

3.4.4.2 Aquatic Ecology

Aquatic Flora

Immediately below the discharge structure, Beaver Dam Creek is characterized by a deep channel (1 to 2.5 meters) and a substrate of shifting sand, fly ash, organic deposits, and occasional clay outcrops (Du Pont, 1985b). Riparian vegetation is dominated by wax myrtle and tag alder. The aquatic flora are sparse, reflecting the influence of high flow and elevated water temperatures.

Aquatic Fauna

Studies conducted for the Comprehensive Cooling Water Study sampled macroinvertebrates from the middle reaches of Beaver Dam Creek between November 1983 and May 1984. In addition, samples were collected from the mouth of Beaver Dam Creek from September 1982 through August 1983 (Du Pont, 1985b; Appendix C).

More species were collected in Beaver Dam Creek than in the other thermally influenced streams (i.e., Four Mile Creek and Pen Branch). Dominant macroinvertebrate species were segmented worms (Oligochaeta), roundworms (Nematoda), midges (Diptera), stoneflies (Plecoptera), and snails (Gastropoda). Also found in lesser abundance were mites (Hydracarina), scuds (Amphipoda), dragonflies (Odonata), and caddisflies (Trichoptera).

The dominant species of adult fish in Beaver Dam Creek are mosquitofish, sunfish, and gizzard shad (Bennett and McFarlane, 1983; Du Pont, 1985b). Relative abundance and species composition increase toward the creek mouth and swamp where greater habitat diversity occurs and temperatures are somewhat moderated (Du Pont, 1985b).

Ichthyoplankton in Beaver Dam Creek reflected the adult composition, with sunfish or bass being dominant. Although thermally influenced, Beaver Dam Creek exhibited greater density and species diversity than the other thermal streams (i.e., Four Mile Creek and Pen Branch), but it did not produce the density expected considering the lower level of thermal loading (Du Pont, 1985b; Appendix C).

3.4.5 RADIOACTIVITY RELEASES AND RADIONUCLIDE TRANSPORT

Approximately 0.004 curie of cesium-137 (decay corrected to 1980) has been released to Beaver Dam Creek from D-Area (Lower and Hayes, 1984). Data on cesium-137 concentrations are not available for Beaver Dam Creek. However, based on the release data, such concentrations are considered to be negligible.

Released tritium remains soluble in Beaver Dam Creek. Approximately 124,100 curies of tritium were released to Beaver Dam Creek from D-Area through 1980 (Du Pont, 1985b).

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CHAPTER 4

ENVIRONMENTAL CONSEQUENCES

This chapter discusses the potential environmental consequences of the construction and operation of the cooling water alternatives for K- and C-Reactors [once-through cooling towers (preferred), recirculating cooling towers, and no action] and the D-Area powerhouse [increased flow with mixing (preferred), direct discharge to the Savannah River, and no action].

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This chapter also discusses the cumulative impacts of the construction and operation of these cooling water alternatives in relation to other Savannah River Plant (SRP) facilities and to major facilities near the Plant, and unavoidable and irreversible impacts of these alternatives.

Sections of this chapter have been expanded to include new data and analyses resulting from the Comprehensive Cooling Water Study (Du Pont, 1985b, 1987) and additional studies conducted in response to public and agency comments on the draft environmental impact statement (EIS). A major change to this chapter is the inclusion of predictive Section 316(a)-type biological data; these data enable a detailed evaluation of the potential impacts of the proposed cooling water alternative systems on the major biological components of the stream ecosystems in relation to the South Carolina water classification standards.

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4.1 ALTERNATIVES FOR K-REACTOR

4.1.1 ONCE-THROUGH COOLING TOWER

As discussed in Section 2.2.1.1, the U.S. Department of Energy (DOE) performed design evaluations and studies to optimize system performance and achieve cost savings in the construction and operation of once-through cooling towers without introducing major changes in the nature or magnitude of environmental impacts. The following description of the potential environmental consequences of constructing and operating a once-through cooling tower for K-Reactor includes a discussion of the major system features that were studied and evaluated.

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4.1.1.1 Construction Impacts

The following sections describe the environmental impacts expected to occur with the construction of a once-through, gravity-feed, natural-draft cooling tower for K-Reactor.

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Socioeconomics

The construction of a once-through cooling tower for K-Reactor would be accomplished in approximately 36 months, after a 9-month lead design period. Construction could involve a combined workforce for the towers in both K- and C-Areas. Two groups of workers would be involved in constructing both towers. The first group, which would include the architect and building crew, would initially number about 60; this would increase to about 100 when work on

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the second cooling tower began because construction of the first tower would be continuing. The second group of workers, which would perform related construction activities such as installing electrical facilities and piping, would involve an estimated peak workforce of 330 workers. These two groups would peak at different times during the construction of the towers. The maximum total construction workforce during these combined activities would not exceed 400; therefore, the estimated peak construction workforce for K-Reactor alone is 200 persons.

TC For planning purposes, average annual construction workforce estimates have been prepared for the next several years for the SRP and for Georgia Power Company's Vogtle Electric Generating Plant (Plant Vogtle), which is in nearby Burke County, Georgia. Table 4-1 lists the projected total levels at both plants from 1987 through 1989. The SRP estimates include the number of workers required to build the cooling towers.

Table 4-1. Projected Total Construction Workforces at Savannah River Plant and Plant Vogtle^a

Location	Workforce		
	FY 1987	FY 1988	FY 1989
Savannah River Plant ^b	5700	6600	4500
Vogtle Nuclear Power Plant	3575	30	0

a. Sources: Du Pont, 1985a; Castrichini, 1985.

b. The size of the SRP construction workforce is subject to change, contingent on changes in DOE authorized programs.

Historic and Archaeological Resources

TC The most recent archaeological and historic resources survey of the Pen Branch watershed area, including Indian Grave Branch, was conducted from May through August 1984, as described in Appendix E. The survey study area encompassed the areas that would be disturbed by facilities associated with a once-through cooling tower for K-Reactor. The survey located 40 sites in the watershed (see Figure E-2 in Appendix E). None of the sites is in an area that would be affected by the construction of once-through cooling-tower system.

Water Quality

The principal impact to water quality in Pen Branch during construction of the once-through cooling-tower system would be temporary increases in suspended solids due to runoff and erosion. Temporary measures such as berms, drainage ditches, drains, sedimentation basins, grassing, and mulching would control

runoff until permanent drainage and erosion control facilities could be completed. Turbidity screens would prevent downstream movement of suspended material where construction activities occur near Four Mile Creek.

Ecology

For a once-through cooling tower with gravity feed, approximately 25 acres of uplands and bottomland hardwoods would be disturbed by the construction, including 19 acres for the gravity flow canals, 2 acres for the cooling tower, and the remaining acreage for the relocation of various other facilities and construction of service roads and parking areas. The effluent canal from the cooling tower to Indian Grave Branch would require the removal of about 0.5 acre of bottomland hardwoods consisting mainly of sweet gum-nuttall oak-willow community.

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Construction activities could temporarily affect certain wildlife species, such as birds and turtles at the construction site. Most of the wildlife would leave the immediate area of construction when activities increase; however, some should return when construction is complete. The clearing of areas for construction would result in the loss of some small mammals, such as shrews and mice; however, significant adverse impacts to the populations are unlikely. When construction has been completed, areas that are no longer needed would be replanted with appropriate grasses, shrubs, or trees and thus made available for use by wildlife.

The expected impacts from sediment loading on fish and macroinvertebrates caused by construction would be minimal because the upper reaches of Pen Branch near the proposed construction are sparsely inhabited at present due to high temperature conditions (Appendix C).

Radiological Releases

During the construction of the once-through cooling tower, there would be no changes in the atmospheric and liquid releases of radionuclides. Reactor operation and the flow rate in Indian Grave Branch and Pen Branch would remain the same. There would be no changes in reactor releases or remobilization of radionuclides from the creek bed and, consequently, radiation doses to the offsite population would not change.

Because the proposed location for the cooling tower is on the SRP, construction personnel for the tower would experience levels of radiation slightly elevated above background, resulting from the operation of Plant facilities. From measurements made at the construction site of the Defense Waste Processing Facility (DWPF; DOE, 1982), augmented by estimates made for that site, the annual dose increment to a construction worker who spends 2000 hours (40 hours per week for 50 weeks per year) in the cooling-tower construction area is approximately 20 millirem. This dose is below the standards of 25 millirem per year from airborne releases and 100 millirem per year from all pathways established by DOE for uncontrolled areas.

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Other Construction Impacts

The construction of the once-through cooling tower for K-Reactor would result in the emission of small quantities of carbon monoxide and hydrocarbons from

engine exhausts of construction equipment and truck traffic, and suspended particulates and dust from ground-surface disturbances. All applicable emissions standards would be met during construction.

Construction of the once-through cooling tower would also cause temporary increases in noise levels in the immediate area from construction equipment such as earth-moving equipment and cranes; however, no noise from these activities is expected to be detectable offsite.

Solid waste generated during construction (excluding clearing debris) would be placed in containers for disposal in an approved manner. Fueling and maintenance of construction equipment would be performed under controlled conditions to minimize spills.

4.1.1.2 Operational Impacts

TE | The following sections present the expected environmental impacts associated with the operation of a once-through cooling tower for K-Reactor. The discussion includes the environmental impacts attributable to the potential operation of a gravity-feed, natural-draft, cooling-tower system.

Socioeconomics

TE | The number of workers associated with the operation of a once-through cooling tower at K-Reactor would not result in any socioeconomic impacts, because only four additional mechanics would be required.

Historic and Archaeological Resources

Operation of the once-through cooling tower with gravity feed would cause no impacts to historic and archaeological resources. During the operation of the cooling tower, effluent would be discharged to Indian Grave Branch, which is a tributary of Pen Branch. Expected flows in Indian Grave Branch and Pen Branch would be nearly the same as those at present, with little change in stream morphology. An archaeological and historic resources survey in the Pen Branch watershed area located no significant sites requiring impact mitigation.

Water Quality and Hydrology

BB-3 | The once-through cooling-tower alternative for K-Reactor would lower the temperature in Pen Branch and the Savannah River swamp. Temperatures, even under extreme 5-day average conditions, would comply with the State of South Carolina's Class B water classification standard of a maximum instream temperature of 32.2°C. However, during certain times of the year, the discharge would raise the stream temperature more than the 2.8°C maximum above ambient specified in the State of South Carolina's Class B water classification standards.

BB-3 | The cooling tower would be designed and operated in a manner that would meet the maximum weekly average temperature (MWAT) criteria (EPA, 1977) to minimize thermal shock of fish that could occur with a reactor outage (Muhlbaier, 1986). Because instream temperatures during winter and spring average conditions probably would be raised by more than 2.8°C above ambient due to

the operation of the cooling-tower system, a Section 316(a) Demonstration study would be performed after operation begins; the results would be submitted to the South Carolina Department of Health and Environmental Control (SCDHEC) in accordance with amended Consent Order 84-4-W. The Section 316(a) study would determine whether effluent temperature conditions would ensure the protection and propagation of a balanced indigenous population of fish, shellfish, and wildlife in and on the waters affected by the discharge.

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The reduction of the temperature in Indian Grave Branch and Pen Branch would cause a corresponding increase in dissolved oxygen concentrations. Studies show that water temperature controls oxygen content in the thermal portions of SRP streams (Du Pont, 1985b, 1987). Under current operating conditions, dissolved oxygen concentrations in Pen Branch are sometimes below South Carolina Class B stream standards during the summer months. Lower water temperatures would produce higher dissolved oxygen concentrations during the summer months, which would result in compliance with water classification standards. The operation of a once-through cooling-tower system would also reduce both the suspended solids discharged to Pen Branch and sedimentation rates in the delta. There are two causes of these effects: First, the reduction of water temperatures would allow some vegetation to develop along the banks of the stream in areas where plants cannot now grow because of the heated discharge water, thereby stabilizing the stream banks and reducing erosion; and second, some of the suspended solids concentrations in the cooling water from the Savannah River would be reduced by settlement in the cooling-tower basin.

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BC-10

BC-10

Effluents discharged to Indian Grave Branch as the result of the implementation of this alternative would be chemically similar to those associated with the present once-through system. Chlorine biocide would be added to reactor cooling water to prevent biofouling of the cooling-tower system and to control the growth of pathogenic organisms that could develop in the heated waters. Chlorine would be neutralized with a sodium sulfite addition prior to discharge to Indian Grave Branch. In bioassay testing conducted at the SRP using K-Reactor effluent (Appendix C; Wilde, 1987), residual chlorine concentrations expected to occur with chlorination of the cooling towers were found to be toxic to representative local fishes (largemouth bass and bluegill). However, after neutralization of residual chlorine with sodium sulfite, the effluent was no longer toxic to these species. The proposed neutralization scheme also was found to cause no significant reductions in dissolved oxygen concentrations or changes in pH (Appendix C; Wilde, 1987). There would be a small increase in the concentration of nonvolatile constituents due to evaporative losses of water from the cooling tower. However, discharges would meet all NPDES permit limits. When K-Reactor is not operating, the concentrations of chemical pollutants in Pen Branch would not change appreciably because of the absence of the cooling water discharge; the stream would meet State Class B water classification standards (see Section 3.2.3 and Du Pont, 1985b, 1987).

BB-1
BB-2

TC

The operation of a once-through cooling tower would result in only small changes to the water flows in Pen Branch and the swamp, compared to present conditions. The evaporation of cooling water from the once-through tower would reduce the discharge flow into the creek from its current level of about 11.3 to about 10.5 cubic meters per second; this would produce no significant

BC-10

BC-10 | change in the water flows in the waterways below the outfall. When K-Reactor is not operating, the flow in Indian Grave Branch and Pen Branch would be reduced significantly.

TE | The operation of the once-through cooling-tower system would produce no
TC | significant impacts on the subsurface hydrology in the area of K-Reactor. Present groundwater discharges from the Barnwell and McBean Formations would continue to discharge to Indian Grave Branch and Pen Branch.

Air Quality

TE | The operation of a once-through, natural-draft cooling tower at K-Reactor could result in the formation of ground-level fog, ice, elevated visible plumes, and total-solids (drift) deposition on the ground. As discussed in Appendix B, a computer model (Fisher, 1974) was used to predict the atmospheric effects of cooling-tower operation. Hourly meteorological data for the period January 1975 to October 1979 were used in the analyses; they were derived from the Savannah River Plant and from the National Weather Service (NWS) station at Bush Field in Augusta, Georgia. Wind and atmospheric stability data collected at 61 meters elevation from the K-Reactor tower and temperature data obtained from the NWS station at Bush Field were the primary sources of meteorological input. For those periods when wind data from the K-Reactor tower were unavailable, data from the other SRP meteorological monitoring stations (described in Section 3.2) were used. If SRP data were not available, wind and atmospheric stability data based on the Pasquill-Turner approach were used, based on data from the Bush Field NWS station.

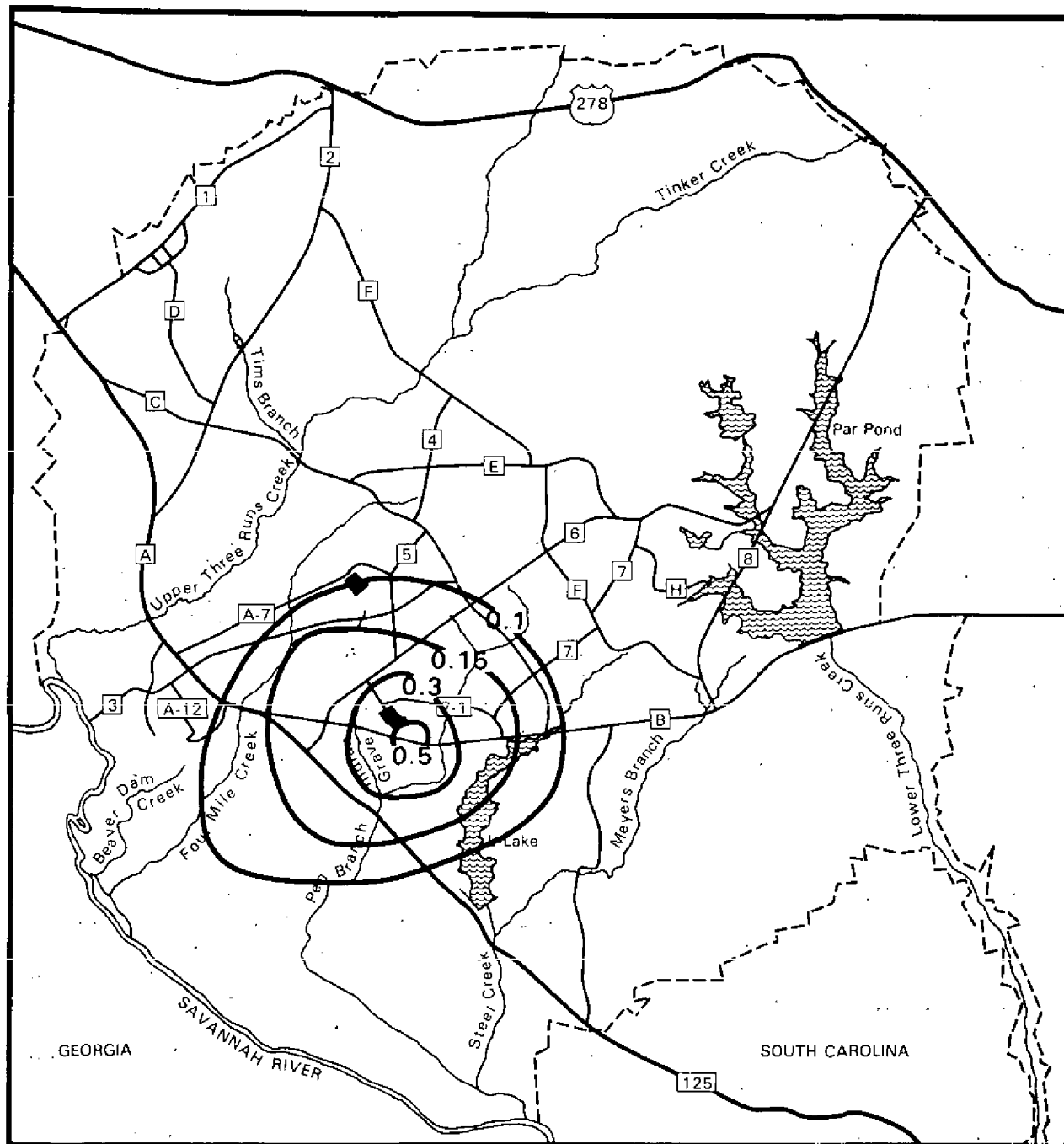
The effects of an evaporative-heat-dissipation system on the formation of fog and ice were determined by the quantity and location of added moisture and by the existing ambient air conditions. The significant factors in determining the increase of fogging and icing are the characteristics and quantity of the effluent air, the height of the effluent plume, and the downwind dispersion of the plume. The fogging calculations were based on the international definition of fog (i.e., the reduction of visibility to less than or equal to 1 kilometer) (Pettersen, 1956).

TC | For the once-through natural-draft cooling tower with gravity feed, the calculated maximum annual mean frequency of reduced ground-level visibility to less than 1000 meters would be less than 2 hours per year for all directions from the K-Reactor cooling tower.

The calculated maximum ice accumulation on horizontal surfaces due to the operation of a once-through natural-draft tower would be no more than 1 millimeter.

TC | The maximum occurrence of visible plumes aloft would be 180 hours per year in the immediate vicinity (0.4 kilometer) of the cooling tower. The plumes would be visible from SRP roads within 2 kilometers of the tower, for approximately 50 hours per year.

TC | Figure 4-1 shows the isopleths of annual total solids deposition due to the operation of the once-through natural-draft cooling tower with gravity feed for K-Reactor.



BB-3

Figure 4-1. K-Reactor Once-Through Tower, Total Solids Deposition, Kilograms/Acre-Year

TC

The calculated maximum annual total-solids deposition (defined as the total amount of solid material deposited as dry particles and in droplet form) would be about 0.5 kilogram per acre per year within 2 kilometers of the tower in all directions.

Noise

TE

The operation of a once-through natural-draft cooling tower with gravity feed at K-Reactor would cause increases in noise levels. Cooling-tower noise would come from falling water. Beyond approximately 152 meters from the cooling tower, average sound levels would be below 70 decibels. [Continuous exposure to 70 decibels or less has been determined to cause no loss of hearing (EPA, 1974).] At the nearest offsite area, noise from K-Area activities would not be detectable.

Ecology

Vegetation and Wetlands

Vegetation near the cooling tower would be subject to salt deposition attributable to drift from the tower. Cooling-tower drift can cause vegetation stress either directly by deposition of salts on the foliage or indirectly from excess accumulations of salts in the soil. Salt stress in plants, which can occur via various mechanisms, includes (1) increased osmotic potential of the soil solution affecting the availability of soil moisture to the plant; (2) alteration of the mineral nutrition balance in the salt tissues; and (3) toxic effects due to specific ion concentrations in the plants (Bernstein, 1975; Hanes, Zelazny, and Blaser, 1970; Allison, 1964; Levitt, 1980).

Tolerances and susceptibility to salt deposition are highly variable, depending on the plant species and on other conditions in the environment. Vegetative studies indicated that thresholds for development of visible salt stress symptoms on the most sensitive species were approximately 83 kilograms per acre per year of sodium chloride salt (INTERA, 1980). Studies indicate that at sodium chloride deposition rates of about 41 kilograms per acre per year, agricultural productivity can be reduced (Mulchi and Armbruster, 1981). Because private agriculture is not permitted on the SRP, vegetative stress, if any, from cooling-tower drift would be limited to the natural plant communities in the vicinity of the towers.

The composition of the drift is equivalent to that of the circulating water. Table 3-3 indicates the concentration of substances in the circulating water for the once-through cooling tower. The substance of particular interest with regard to its potential for damage is the chloride ion. The other constituents listed in Table 3-3 either are at concentrations low enough to be negligible or are potentially beneficial.

TC

The operation of a once-through natural-draft cooling tower with gravity feed would result in an estimated total solids deposition of about 0.5 kilogram per acre per year within 2 kilometers. The sodium chloride deposition rates from the cooling tower would be much less than the critical values (reported by

Mulchi and Armbruster, 1981 and INTERA, 1980) that can cause reduced productivity of plant species. Therefore, no significant impacts on vegetation are expected. TC

The most significant impact on the vegetation resulting from operation of a once-through cooling-tower system would be a reduction in the loss of wetland habitat due to thermal discharges. Because the stream would still be subject to variable flows, there would be incomplete reestablishment of upstream wetland communities along Indian Grave Branch and Pen Branch. From 1955 through 1984, about 670 acres of wetlands were affected in the Pen Branch floodplain and swamp due to thermal discharges and flooding (Du Pont, 1985b, 1987; Appendix F), with an average loss of about 26 acres per year in the swamp. The operation of a once-through cooling-tower system would eliminate additional losses in the stream corridor. Thermal effects are one of the three major factors (the others are flooding from reactor operation and river flooding) responsible for continuing swamp canopy loss (Du Pont, 1985b, 1987). The reduction in effluent temperatures would, therefore, have a positive effect on wetland communities by significantly reducing wetland loss rates. TC

To assist in ongoing consultations with the U.S. Fish and Wildlife Service (FWS), a Habitat Evaluation Procedure (HEP) analysis (Mackey et al., 1987) was conducted; this procedure identified the value of habitat to be gained or lost with the once-through cooling-tower alternative (see Section 4.6 and Appendix C for more details on HEP analysis). BC-3

Aquatic Habitat and Biota

Balanced communities containing indigenous species in all biotic categories should develop and remain in all natural portions of the Pen Branch ecosystem following the implementation of a once-through cooling-tower system for K-Reactor. Predicted maximum water temperatures in the immediate discharge area would be below the maximum of 32.2°C required for Class B waters of the State of South Carolina. However, the other temperature criterion for Class B waters (maximum temperature change of 2.8°C) would sometimes be exceeded in the stream. Accordingly, a Section 316(a) Demonstration study would be conducted to determine if a balanced biological community would be maintained.

To compare and assess environmental impacts to the Pen Branch watershed before and after operation of the once-through cooling system, the stream system has been divided into three reaches based on the presence of distinct stream gradients: Reach 1 extends from the K-Reactor outlet down to SRP Road A, Reach 2 extends from SRP Road A to the mouth of the Pen Branch delta, and Reach 3 extends from the Pen Branch delta to the Savannah River. BB-3

Conditions for all biotic categories would be greatly enhanced following mitigation in comparison to present conditions. Based on extensive data from Steel Creek, which had been impacted previously, recolonization of areas within the Pen Branch system that are presently uninhabitable because of excessive temperatures would occur rapidly. Furthermore, an analysis of the temperature requirements of the representative and important species indigenous to the creek system has revealed that these species would not be

affected adversely by the higher-than-ambient temperatures resulting from K-Reactor operation following mitigation with the once-through cooling-tower system (Du Pont, 1987).

The Pen Branch system, which includes Pen Branch and Indian Grave Branch, is a low potential impact area for phytoplankton. The food base throughout this system consists of detrital material rather than phytoplankton, as is typical in lotic systems. Primary producers in the Pen Branch system consist mainly of periphyton and macrophytes (Du Pont, 1985b, 1987).

Following the implementation of a once-through cooling tower, zooplankton would become established in the primary study area. This newly established zooplankton community would provide food for the establishment of balanced indigenous macroinvertebrate and fish communities. The maximum predicted summer temperatures in the Pen Branch system would be within the range tolerated by most, if not all, indigenous species; accordingly, the heated discharge should cause no appreciable harm to the zooplankton community. The standing crop of zooplankton could be enhanced by the relatively slight temperature elevations above ambient, and species composition and community structure should be similar to those of the Pen Branch system before K-Reactor operation and to those of other natural streams in the region. The heated discharge is not likely to alter the standing crop, community structure, or seasonal periodicity of zooplankton in the farfield study area from those values typical of the receiving water body segment before reactor operation. Furthermore, cooling-tower discharge flow would not constitute a lethal barrier to the free movement (drift) of zooplankton.

BB-3

The habitat-formers community would improve with the addition of a once-through cooling tower for K-Reactor. However, the pattern of recovery is difficult to predict. Unlike the Steel Creek delta, which in early 1968 stopped receiving both high flow and temperature from L-Reactor, temperatures will become reduced, but high flow will remain from the K-Reactor tower.

At present, much of the Pen Branch system (especially Reaches 1 and 2) have temperatures that exceed the thermal tolerances of many aquatic plants. The reduction of temperatures to below lethal limits would allow the establishment of macrophytes and other aquatic plants, especially into Reaches 2 and 3. Reach 1 (Indian Grave Branch) is in a steeper, higher gradient stream valley than the rest of Pen Branch; macrophytes and other vascular flora are not as likely to develop there. Reaches 2 and 3 have lower gradients, are more open, and are more conducive to the establishment of mature plant communities. However, the high flows from the cooling tower probably would impede the types of vegetative communities that could develop. A reduction of macrophyte growth in the main channel caused by an increase in flow has been observed in Lower Three Runs Creek. A reduction in the size of macrophyte beds (Polygonum) has been observed in Steel Creek along the main channels after increased flows in Steel Creek since the restart of L-Reactor in October 1985. Macrophyte development in Pen Branch probably would be restricted to the edges of the islands throughout Reaches 2 and 3. Typha, Ludwigia, Cyperus, Sagittaria, Leersia, Hydrolea, and Polygonum should become established along the channel margins and in backwater areas of reduced flow. Due to high flows and changing water levels, macrophytes would be uncommon in the main portions of the stream channels. In deeper water areas of slow flow,

Ceratophyllum and Myriophyllum could be abundant. Buttonbush and willow should continue to develop in areas of reduced temperatures, provided flooding and erosion of islands through channel modification is not extensive. Algae, including blue-green species, should continue to be common in the warmer months due to nutrient loading from the cooling tower (Du Pont, 1987).

The reduced temperature regime resulting from the cooling tower would permit the invasion of some species of aquatic macrophytes and periphyton in parts of the system that are presently too hot to support plant life. However, rapid water velocities and a scoured stream substrate would make root penetration difficult; these conditions are expected to retard the development of macrophyte communities in the center of the stream channel. In contrast, good development of aquatic macrophyte and riparian communities is expected along the stream margins, as well as in the delta area, where the stream channel is braided and water velocities are reduced.

The combination of above-ambient temperatures and the nutrient-rich river water that is used for reactor cooling should result in higher levels of primary production than would occur without reactor discharge. In addition, much more aquatic habitat would exist with a once-through cooling tower than would exist without the reactor discharge, because of the higher water levels.

However, flow fluctuations during reactor cycling would result in the dewatering and subsequent dessication of large areas of stream bottom during reactor outages. The flow fluctuations probably would result in a macrophyte community dominated primarily by emergent species that could withstand dewatering, although some submerged macrophyte species probably would become established in pools and backwater areas. The dewatering also would impact periphyton communities, causing major die-offs during reactor outages. Thus, although conditions with the cooling tower would be improved over existing conditions due to reductions in stream temperatures, flow fluctuations would perturb the ecosystems of the stream corridor and delta areas to some extent and would influence the types of communities that would develop in these areas.

BB-3

A once-through cooling tower would reduce stream water temperatures (see Chapter 2 and Appendix B) in comparison to present conditions, and would provide a thermal regime in the Pen Branch system conducive to the establishment of a reasonably diverse macroinvertebrate community. Following implementation of this alternative, the maximum predicted temperatures in the three reaches of the stream would be within the range tolerated by most, if not all, indigenous macroinvertebrate species.

Macroinvertebrates that utilize detritus (i.e., dead algae and other organic material; collector-gatherers and collector-filterers) probably would be favored in Pen Branch. In time, as riparian vegetation develops and begins to shed leaves into the stream, the relative abundance of shredders should increase. Organisms with short generation times (less than 1 month) should have a competitive advantage over longer-lived species, because they probably would be able to complete one or more life cycles during a single reactor cycle. Mobility would also be a factor in determining the macroinvertebrate species composition of Pen Branch, because species that can move quickly into deeper water or that can enter the drift rapidly would be favored over more sessile species. Species that can resist dessication in one or more life stage would have a competitive advantage.

Numerically, the chironomids should continue to dominate the macroinvertebrate community of the Pen Branch corridor, as they do in most southeastern streams (Smock et al., 1985). The dominant chironomid taxa, however, would shift, with the more thermally tolerant species being replaced by other species that are not thermally tolerant. Organisms (e.g., mayflies and beetles) that can migrate quickly would be favored in Pen Branch, while sessile organisms, as well as taxa that pupate in the water (e.g., caddisflies) could experience high rates of mortality during reactor outages. Species that inhabit the stream substrate might not be greatly impacted, except during extended reactor outages, when discharges could be reduced long enough to dry out portions of the stream substrate completely. Although Pen Branch should support a reasonably diverse macroinvertebrate community, fluctuations in water level and an elevated temperature regime could preclude the establishment of some of the more sensitive macroinvertebrate taxa in the stream.

Although above-ambient temperatures should produce earlier emergence of many species of aquatic insects, no major adverse impacts should occur. The slightly elevated temperatures could permit multivoltine species of insects (those that complete more than one life cycle per year) to produce one or more additional generations per year, thereby increasing the net annual production of the macroinvertebrate community.

BB-3 The fluctuating water levels during reactor cycling would affect the macroinvertebrate community of Pen Branch to some extent. Increased drift would occur during rising and receding water levels, which could result in increased predation and possibly temporary reductions in standing crop. Dewatering of macroinvertebrate habitat (logs, leaf packs, stream substrate, etc.) during reactor outages could result in substantial mortality for some species of macroinvertebrates. If large periphyton die-offs are caused by dewatering, secondary production could be reduced temporarily due to the reduced availability of food. However, the standing crop of macroinvertebrates in Pen Branch should be sufficient to ensure a good supply of food for higher trophic levels (i.e., fish).

The cooling-tower discharge flow would not interfere with the drift or upstream movement of macroinvertebrates, because the predicted maximum temperature of the plume would be less than the upper thermal limits of most macroinvertebrate species indigenous to the southeast. No significant farfield impacts should occur, because the water would be near ambient temperature by the time it reaches the Savannah River (see Appendix B, Table B-4).

A once-through cooling tower would improve conditions for the fish communities in the Pen Branch system. The community in upper Pen Branch above K-Reactor is not expected to change substantially from present conditions, because the fish communities in the upper reaches of SRP tributary streams appear to be stable and not affected significantly by reactor operations. One major difference caused by cooling-tower operation could enhance the fish community in this portion of the stream system. Water temperatures at the confluence of Indian Grave Branch and Pen Branch would never exceed 32°C or have an average monthly ΔT greater than 10°C (winter; see Appendix B, Table B-4). Accordingly, water temperature should not inhibit the movement of fish between the Savannah River and the headwaters of Pen Branch. This could result in

additional spawning in the upper reaches and could provide a pathway for immature fishes spawned in these reaches to contribute to the populations in Reaches 1, 2, and 3 below K-Reactor and in the Savannah River.

Following implementation of this alternative, a temperature-restricted zone of passage in Reach 1 should not exist; this would allow fish to reinvade this section and could provide spawning and nursery areas for some species. Maximum temperatures in Reach 2 would not exceed 32°C and average monthly ΔT values would not exceed 10°C (see Appendix B, Table B-4); this should allow indigenous fish species to inhabit Reach 2. Some areas of Reach 2 should be suitable for spawning, thereby increasing fish populations. Furthermore, the addition of slightly heated and relatively nutrient-rich Savannah River water to Pen Branch via the cooling-tower discharge should increase primary and secondary production in this area. The result would be an enhancement of fish growth in this portion of the creek in comparison to expected fish growth under ambient conditions. All of Reach 3 should be suitable habitat for all indigenous fishes of the Pen Branch system. Water temperatures should not exceed 31°C and average monthly ΔT values would not exceed 8°C in this region during the winter (see Appendix B, Table B-4). Reactor operation should have no adverse impact on reproduction. Growth should be enhanced by the increased productivity resulting from the slight temperature elevation and nutrient loading from Savannah River water pumped through the system.

The maximum predicted water temperature at the cooling-tower discharge point would be 32°C (see Appendix B, Table B-4) and the maximum predicted average monthly temperature would be 29°C. In contrast, the upper incipient lethal temperatures for representative and important species (largemouth bass, bluegill, and catfish) are in the mid- to upper 30s°C. The cooling-tower system would comply with the temperature shock limits proposed by the U.S. Environmental Protection Agency (EPA) for the protection of all warm-water fishes (EPA, 1977). Laboratory studies have shown these limits to be protective of the temperature tolerance limits of largemouth bass, bluegill, and channel catfish (Wilde, 1987; Storms, 1985). Reproductive success and growth of all indigenous fish species should be improved over present conditions by implementation of this alternative; growth could be enhanced even above potential ambient temperature levels because the slight warming from the cooling-tower discharge would result in optimal growth temperatures for more of the year than with ambient conditions. Maximal absolute temperatures and ΔT s should not block fish migration. Thus, the entire Pen Branch system should be available for fish habitation; the free movement of fishes between the headwaters of Pen Branch and the Savannah River should not be inhibited by K-Reactor operations at any time during the year. The thermal discharge flow should not block fish migration or exclude fish from any part of the ecosystem.

BB-3

Entrainment and Impingement

The operation of a once-through cooling tower would not require any changes to the intake cooling water flow rates. Accordingly, expected entrainment and impingement impacts would be similar to current impacts for K-Reactor.

The entrainment rates at the 1G and 3G intakes, as determined by onsite studies conducted annually from 1983 to 1985 (DOE, 1987), result in the average loss of approximately 17.6×10^6 fish larvae (range: 10.2×10^6 to 26.1×10^6 fish larvae; Appendix C) during the February-to-July spawning season at the Plant. Estimated losses of fish eggs average 9.3×10^6 (range: 5.3×10^6 to 14.0×10^6 eggs; Appendix C) each spawning season. Because about 50 percent of the water drawn into the two intakes is used for cooling K-Reactor, about half the total loss of larvae (8.8×10^6) and eggs (4.6×10^6) can be attributed to the operation of this facility. The taxonomic groups whose larvae are most impacted by entrainment through the 1G and 3G intakes are the Clupeidae (shad, herring, etc.) the Centrarchidae (crappie, sunfish, etc.), and the Cyprinidae (carp, etc.). The eggs of the American shad and striped bass were entrained most often, accounting for an average 73 percent of all eggs entrained.

BB-3 Overall entrainment losses for K-Reactor operation averaged approximately 5.4 percent (range: 4.4 to 7.5 percent) of the ichthyoplankton passing the SRP intakes (DOE, 1987). Egg losses were concentrated among two anadromous species, American shad and striped bass, but only populations spawning in the 30 miles of the river between the New Savannah Bluff Lock and Dam and the SRP are affected. American shad and striped bass spawn throughout the Savannah River, but the primary region for striped bass spawning is in the tidally influenced portions of the river near Savannah. Entrainment of ichthyoplankton of fresh water species primarily affects the eggs and larvae of individuals that spawn in the vicinity of the intake canals, either in the river or in the 1G and 3G canals. Consequently, the effect of entrainment of fish eggs and larvae should be small and restricted to local fish populations.

The current rates of impingement at the 1G and 3G intake screens would not be expected to change with a once-through cooling-tower system. During investigations conducted annually from 1983 to 1985 (DOE, 1987), projected annual impingement for the two intakes combined averaged approximately 5885 fish (range: 2986 to 9534 fish per year; Appendix C), about half (2942 fish per year) of which can be attributed to K-Reactor. The principal species affected were bluespotted sunfish and threadfin shad; gizzard shad, redbreast sunfish, and warmouth were also impinged frequently.

Threatened and Endangered Species

Several inactive red-cockaded woodpecker colonies are located in the Pen Branch area. However, because the preferred habitat of this species is mature pine forests rather than wetland or bottomland hardwoods near the creek, the operation of the once-through cooling tower would not impact the habitat of this endangered woodpecker.

BB-3 The American alligator occurs on the SRP site in both flowing-water and lake environments. Temperatures in the thermal region of Pen Branch under present operating conditions are higher than 50°C in the summer, which exceeds the critical thermal maximum of 38°C for the alligator. Thus, alligators cannot inhabit major portions of the stream during reactor operation. This alternative would improve habitat quality over existing conditions; however, fluctuating water levels and elevated water temperatures could affect this

species adversely by flooding nests, eggs, and hibernation sites. Elevated temperatures during the winter and spring months could influence reproduction, nesting, and survival by hastening sexual maturation and nesting in the spring.

BB-3

The federally endangered bald eagle is a fairly common permanent breeding resident in South Carolina and is most abundant in the coastal region; it migrates from the southeast to the northern states and Canada in mid-summer and returns south in the fall and early winter to nest and rear its young (Sprunt and Chamberlain, 1970). The presence of this species on Par Pond was first recorded in May 1959 (Norris, 1963); eagles have been sighted frequently on the SRP since 1978 (Mayer et al., 1986).

TC

The first sighting of an active bald eagle nest on the SRP occurred on June 5, 1986. The nest contained two eaglets. In 1987, the mating pair returned to their nest and fledged two eaglets. The nest is located below Par Pond dam in the Lower Three Runs Creek drainage area. Because this nest is outside the preferred alternative cooling impact zones and due to the implementation of management practices in accordance with the guidelines of the 1984 bald eagle recovery plan, the U.S. Fish and Wildlife Service (FWS) issued a finding of no effect to this species in 1986 (Henry, 1986).

Although shortnose sturgeon larvae and adults have been collected from the Savannah River and the intake canals, no shortnose sturgeon have been collected from any SRP creeks, nor do these areas provide spawning habitat. Current SRP operations have been determined to have no adverse impact on the endangered shortnose sturgeon population in the Savannah River (Oravetz, 1983).

A total of 59 endangered wood storks were observed foraging in the Pen Branch delta from 1983 through 1986 (Du Pont, 1987). The high flow rate, water depth, and lengthy reactor cycles associated with the operation of K-Reactor and a once-through cooling tower could minimize the availability of quality foraging habitat for the wood stork.

BB-3

Formal consultation was held between DOE and FWS on the bald eagle, American alligator, red-cockaded woodpecker, and wood stork. Based on this consultation, the FWS issued a biological opinion that the preferred alternative cooling systems should have no effect on endangered and threatened species (Parker, 1986; Henry, 1986). In addition, the National Marine Fisheries Service (NMFS) has previously concurred in DOE's determination that the population of shortnose sturgeon in the Savannah River would not be affected adversely by SRP operations (Oravetz, 1983).

TC

Radiological Releases

The radiological releases associated with the discharge of cooling water from K-Reactor are those resulting from either the remobilization of radionuclides contained in the Indian Grave Branch and Pen Branch streambeds and floodplain, or those resulting from small process-water leaks into the cooling water.

The operation of the once-through cooling tower would not result in any significant changes in the remobilization of radionuclides contained in the streambed and floodplain, because the flow rate of cooling water discharged to the creek would remain essentially unchanged. The operation of the cooling

tower, however, would decrease the amount of tritium discharged to the stream and, correspondingly, would increase the amount of tritium released to the atmosphere because of evaporation from the tower. The following sections discuss changes in the doses to the maximally exposed individual at the SRP boundary and to offsite population groups (based on Year 2000 projections) attributable to the change in atmospheric and liquid releases of tritium resulting from operation of the cooling tower.

Appendix G contains details of the dose assessment methodology and parameters; it also contains tables that list specific organ doses by pathway and age group.

Atmospheric Releases

TE | The amount of tritium released to the atmosphere is expected to increase by 50 curies per year (about 0.012 percent of total SRP releases of tritium to the atmosphere) as a result of cooling water evaporation. This release would increase the atmospheric dose commitments of the regional population and the maximally exposed individual. Changes in dose commitments resulting from the increased release of atmospheric tritium are summarized below.

TC | Maximum Individual Dose - The hypothetical individual who would receive the highest effective whole-body dose from atmospheric releases associated with this cooling alternative is assumed to reside continuously at the SRP boundary about 8.8 kilometers west of K-Reactor. This location has the minimum atmospheric dilution, based on distance to the Plant boundary and meteorological dispersion characteristics. This individual is assumed to receive doses by inhalation and by the ingestion of meat, vegetation, and cow's milk.

The annual increase in soft-tissue and effective whole-body doses to the maximally exposed individual due to the atmospheric release of tritium is summarized in Table 4-2.

TE | Population Dose - Collective doses resulting from atmospheric releases associated with this cooling alternative have been calculated for the population within 80 kilometers of the Plant. The annual effective whole-body dose to this population would increase by 4.97×10^{-3} person-rem as a result of the increase in tritium released to the atmosphere.

TC | Liquid Releases

TE | The operation of the once-through cooling tower would reduce the amount of tritium released to Pen Branch. The release of tritium would decrease by 50 curies per year (about 0.12 percent of total releases of tritium to streams) as a result of the evaporation of cooling water in the tower. Doses associated with the change in liquid releases are discussed below for both the population and the maximally exposed individual.

Maximum Individual Dose - The hypothetical individual who would experience the greatest change in dose from liquid effluents is assumed to live near the Savannah River downstream from the Savannah River Plant. The individual is assumed to use river water regularly for drinking, to consume fish from the

Table 4-2. Increase in Annual Doses to Maximally Exposed Individual Resulting from Atmospheric Releases of Tritium from K-Reactor Once-Through Cooling Tower

Incremental dose increase (mrem/yr)		
Age group	Effective whole body	All soft tissue ^a
Adult	1.05×10^{-4}	1.23×10^{-4}
Teen	1.14×10^{-4}	1.34×10^{-4}
Child	7.86×10^{-5}	9.24×10^{-5}
Infant	2.33×10^{-5}	2.74×10^{-5}

a. Tritium imparts an equal dose to all soft tissues (i.e., all organs except bone) that is about 18 percent higher than the effective whole-body dose.

river, and to experience external exposures from shoreline activities. The individual is also assumed to drink more water and eat more fish than an average person.

Table 4-3 summarizes the annual decrease in soft-tissue and effective whole-body doses received by the maximally exposed individual due to a decrease in the liquid release of tritium.

Population Dose - Savannah River water is not used for drinking within 80 kilometers downstream of the Savannah River Plant; therefore, the dose to the population in this area would come from fish and shellfish consumption, and shoreline activities.

The decrease in the collective dose to the Year-2000 population of 852,000 within 80 kilometers of the Savannah River Plant from liquid releases of tritium associated with this cooling alternative would be 2.46×10^{-5} person-rem per year (Table 4-4).

The Beaufort-Jasper and Port Wentworth population groups use the Savannah River as a source of potable water. While these groups are more than 80 kilometers from the Savannah River Plant (about 100 river miles downstream), their drinking-water doses have been calculated. The decrease in the collective dose delivered to these populations (an estimated 317,000 people will consume water from the Beaufort-Jasper and Port Wentworth water-treatment plants by the Year 2000) from tritium in drinking water is 3.26×10^{-2} person rem per year, as presented in Table 4-4.

Table 4-3. Decrease in Annual Doses to Maximally Exposed Individual Resulting from a Decrease in Liquid Releases of Tritium from K-Reactor Once-Through Cooling Tower

Incremental dose reduction (mrem/yr)		
Age group	Effective whole body	All soft tissue ^a
Adult	2.19×10^{-4}	2.58×10^{-4}
Teen	1.54×10^{-4}	1.81×10^{-4}
Child	1.50×10^{-4}	1.76×10^{-4}
Infant	9.52×10^{-5}	1.12×10^{-4}

a. Tritium imparts an equal dose to all soft tissues (i.e., all organs except bone) that is about 18 percent higher than the effective whole-body dose.

Table 4-4. Decrease in Collective Effective Whole-Body Dose Resulting from Liquid Releases of Tritium from K-Reactor Once-Through Cooling Tower

Population group	Incremental collective dose reduction (person-rem/yr)
80-kilometer radius	2.46×10^{-5}
Beaufort-Jasper	1.13×10^{-2}
Port Wentworth	2.13×10^{-2}
Total	3.26×10^{-2}

Overall Changes in Offsite Doses

Table 4-5 summarizes changes in the effective whole-body dose received by the maximally exposed individual resulting from the operation of this cooling alternative. Table 4-6 indicates changes in the collective dose.

Table 4-5. Changes in Effective Whole-Body Dose Received by Maximally Exposed Individual Resulting from Operation of K-Reactor Once-Through Cooling Tower (millirem per year)^a

Source of exposure	Adult	Teen	Child	Infant
Atmospheric tritium releases	1.05×10^{-4}	1.14×10^{-4}	7.86×10^{-5}	2.33×10^{-5}
Liquid tritium releases	$-2.19 \times 10^{-4} \text{ (b)}$	-1.54×10^{-4}	-1.50×10^{-4}	-9.52×10^{-5}
Net dose change	-1.14×10^{-4}	-4.00×10^{-5}	-7.14×10^{-5}	-7.19×10^{-5}

a. Tritium imparts an equal dose to all soft tissues that is about 18 percent higher than the effective whole-body dose.

b. Negative sign denotes a decrease in dose.

The average background total-body dose to an individual living in the vicinity of the Savannah River Plant is 93 millirem per year. By extrapolation, the annual collective dose to the 80-kilometer population is 79,200 person-rem; to the Port Wentworth water users, it is 18,600 person-rem; and to the Beaufort-Jasper water users, 10,900 person-rem.

TE

This cooling alternative would reduce the annual dose to the effective whole body of the maximally exposed adult and the annual collective effective whole-body dose to Port Wentworth and Beaufort-Jasper water users by 1.14×10^{-4} millirem, 2.13×10^{-2} person-rem, and 1.13×10^{-2} person-rem, respectively; it also would increase the collective effective whole-body dose to the 80-kilometer population by 4.95×10^{-3} person-rem per year. These dose changes are very small compared to the normal year-to-year variations in natural background radiation.

BC-22

Present tritium releases to the Savannah River from Indian Grave Branch and Pen Branch result in an effective whole-body dose of 5.18×10^{-2} millirem per year to the maximally exposed adult. This alternative would reduce the liquid tritium dose by 2.19×10^{-4} millirem per year and increase the atmospheric dose by 1.05×10^{-4} millirem per year, resulting in an overall reduction of 1.14×10^{-4} millirem per year.

BC-22

Health Effects

Risk estimators used to project health effects are 120 fatal cancers and 257 genetic effects per 1 million person-rem of collective dose; Appendix G presents the risk estimators by organ. According to these estimators and the organ doses, the population within 80 kilometers of the SRP could experience an annual increase of 5.82×10^{-7} excess cancer fatality and 1.50×10^{-6} additional genetic disorder from the operation of this alternative cooling water system. The populations at Beaufort-Jasper and Port Wentworth downstream from the Plant could experience decreases of 3.84×10^{-6} fatal

Table 4-6. Changes in Collective Effective Whole-Body Dose Resulting from Operation of K-Reactor Once-Through Cooling Tower (person-rem per year)

Source of exposure	80-kilometer population	Beaufort-Jasper	Port Wentworth	Total
Atmospheric tritium releases	4.97×10^{-3}	--	--	4.97×10^{-3}
Liquid tritium releases ^a	-2.46×10^{-5}	-1.13×10^{-2}	-2.13×10^{-2}	-3.26×10^{-2}
Net dose change	4.95×10^{-3}	-1.13×10^{-2}	-2.13×10^{-2}	-2.77×10^{-2}

a. Negative sign denotes a decrease in dose.

BC-22

cancer and 9.87×10^{-6} genetic disorder per year. Table 4-7 summarizes this information.

Table 4-7. Changes in Annual Health Effects

Population group	Genetic disorders	Fatal cancers
80-kilometer radius	1.50×10^{-6}	5.82×10^{-7}
Beaufort-Jasper ^a	-3.42×10^{-6}	-1.33×10^{-6}
Port Wentworth	-6.45×10^{-6}	-2.51×10^{-6}
Total	-8.37×10^{-6}	-3.26×10^{-6}

a. Negative sign denotes a decrease in health effects.

4.1.2 RECIRCULATING COOLING TOWERS

4.1.2.1 Construction Impacts

Socioeconomics

Construction of the recirculating cooling towers for K-Reactor would be accomplished in approximately 42 months after a 9-month lead design period. This construction could involve a combined workforce for the towers in K- and C-Areas. Two groups of workers would be involved in constructing these cooling towers. The first group, which would include the architect and building crew, would initially number about 90. This group would increase to about 150 when work on the cooling towers for C-Reactor began because construction of the towers for K-Reactor would be continuing. The second group of workers would perform related construction activities, such as installing electrical facilities and piping; this group would involve a peak workforce of 490 personnel. The two workforce groups would peak at different times during construction. The maximum total construction workforce during these combined activities would not exceed 600; therefore, the estimated peak construction workforce for K-Reactor alone is 300 persons.

TC

As described in Section 4.1.1.1, construction workers from other local projects would be available for employment on the Plant. Because these workers already reside in the SRP area, no impacts to local communities and services due to immigrating workers would occur.

Historic and Archaeological Resources

No sites within the Pen Branch and Indian Grave Branch watershed area would be affected by the construction of recirculating cooling towers (see Appendix E for more details).

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Water Quality

The impacts on water quality in Indian Grave Branch and Pen Branch from the construction of recirculating cooling towers would be similar to those associated with the construction of a once-through cooling tower (see Section 4.1.1.1). The principal impact would be some temporary localized increases in the concentration of suspended material in the stream water due to runoff and erosion from construction activities. The application of standard erosion control practices, described in Section 4.1.1.1, would minimize these temporary effects.

Ecology

The construction of recirculating cooling towers would disturb about 50 acres of upland forest (21 acres for the cooling towers, 27 acres for the canal and pipeline right-of-ways, and the remainder for relocation of various facilities and for the construction of service roads and parking areas). No adverse effects on vegetation should occur outside the immediate construction areas.

The impacts to fish and wildlife from the construction of the recirculating cooling towers would be similar to those described for the construction of a once-through cooling tower (see Section 4.1.1.1).

Radiological Releases

During the construction of recirculating cooling towers for K-Reactor, there would be no changes in the atmospheric and liquid releases of radionuclides. Reactor operation and the flow rate in Indian Grave Branch and Pen Branch would remain the same. There would be no changes in reactor releases or remobilization of radionuclides from the creek bed and, consequently, radiation doses to the offsite population would not change.

The only change would be in doses delivered to onsite construction personnel, as discussed in Section 4.1.1.1. This dose, estimated to be approximately 20 millirem per year, is below the standards established by DOE for uncontrolled areas of 25 millirem per year from airborne releases and 100 millirem per year from all pathways.

Other Construction Impacts

The construction of recirculating cooling towers for K-Reactor would also result in air quality and noise impacts similar to those described for the once-through cooling tower (Section 4.1.1.1). All applicable atmospheric emission standards would be met during construction, and solid waste generated during construction would be disposed of in an approved manner. Fueling and maintenance of construction equipment would be performed under controlled conditions to minimize spills.

4.1.2.2 Operational Impacts

Socioeconomics

The number of workers associated with the operation of recirculating cooling towers at K-Reactor would not result in any socioeconomic impacts, because only six additional mechanics would be required.

Historic and Archaeological Resources

The operation of recirculating cooling towers for K-Reactor would not cause any impacts to any historic and archaeological resources. During the operation of the towers, cooling water effluent would be conveyed to Indian Grave Branch and Pen Branch; flows in the creek would be significantly reduced. An archaeological and historic resources survey in the Four Mile Creek watershed area located no significant sites requiring impact mitigation (Appendix E).

Water Quality and Hydrology

The operation of recirculating cooling towers would lower discharge temperatures such that the State of South Carolina's Class B water classification standards (i.e., a maximum instream temperature of 32.2°C) would be met throughout the year. The discharge from the recirculating cooling tower would raise the stream temperature in Pen Branch more than the 2.8°C maximum above ambient specified in the State's Class B water classification standards. Accordingly, a Section 316(a) study would be performed to demonstrate if a balanced biological community would be maintained.

The operation of the recirculating cooling towers would result in discharges to Indian Grave Branch and Pen Branch, with concentrations of most chemical constituents about three times higher than corresponding values for Savannah River water drawn into the intakes, due to evaporative concentrations in the recirculating tower. An important difference between the compositions of river water and ambient creek water is the higher concentration of phosphorus and nitrogen compounds (i.e., orthophosphate, total phosphorus, nitrates, and ammonia) in the river. Although the concentrations of chemical constituents (e.g., nutrients) would increase by about three times due to cycling in the recirculating tower, the total quantity of nutrients and other chemicals transported to the swamp river system would decrease because the intake flow of Savannah River water for this alternative would be much less than either the present cooling water system or the once-through cooling-tower alternative. Chlorine biocide added to reactor cooling water to prevent biofouling of the cooling towers would be neutralized with sodium sulfite addition prior to discharge to Indian Grave Branch. As discussed for the once-through cooling-tower alternative, no adverse effects should occur to aquatic biota or water quality from these additions. All discharges would comply with NPDES permit requirements and State Class B water classification standards.

With the operation of recirculating cooling towers, dissolved oxygen levels in Indian Grave Branch and Pen Branch should comply with Class B water

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classification standards throughout the year as a result of lower discharge water temperatures and the aeration resulting from water passing through the cooling towers. Under present conditions, dissolved oxygen concentrations sometimes fall below Class B water classification standards (5 milligrams per liter average; 4 milligrams per liter minimum) during warmer summer periods. The lower flow in the stream would reduce erosion, and the lower water temperatures would allow vegetation to grow along the waterway, thereby stabilizing the shoreline areas. Thus, the levels of total suspended solids would be lower in Indian Grave Branch and Pen Branch and the Savannah River swamp.

BC-9
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The operation of recirculating cooling towers would have a significant effect on the hydrology of Indian Grave Branch and Pen Branch due to a reduction in discharge flow from the present level of about 11.3 cubic meters to about 1 cubic meter per second. The flow in the creek from areas upstream of K-Reactor is about 0.03 cubic meter per second. Under these conditions, the morphology of the stream channel would be altered significantly; generally, its depth and width would be reduced. Existing patterns and rates of erosion and deposition would change; one of the most important results would be a significant reduction in the rate of delta growth. The overall impact of the reduction in flow on the hydrology of the swamp would be small because the Savannah River is the principal factor influencing hydrological conditions in the swamp.

Impacts to subsurface hydrology would be similar to those discussed in Section 4.1.1.2 for the once-through cooling tower.

Air Quality

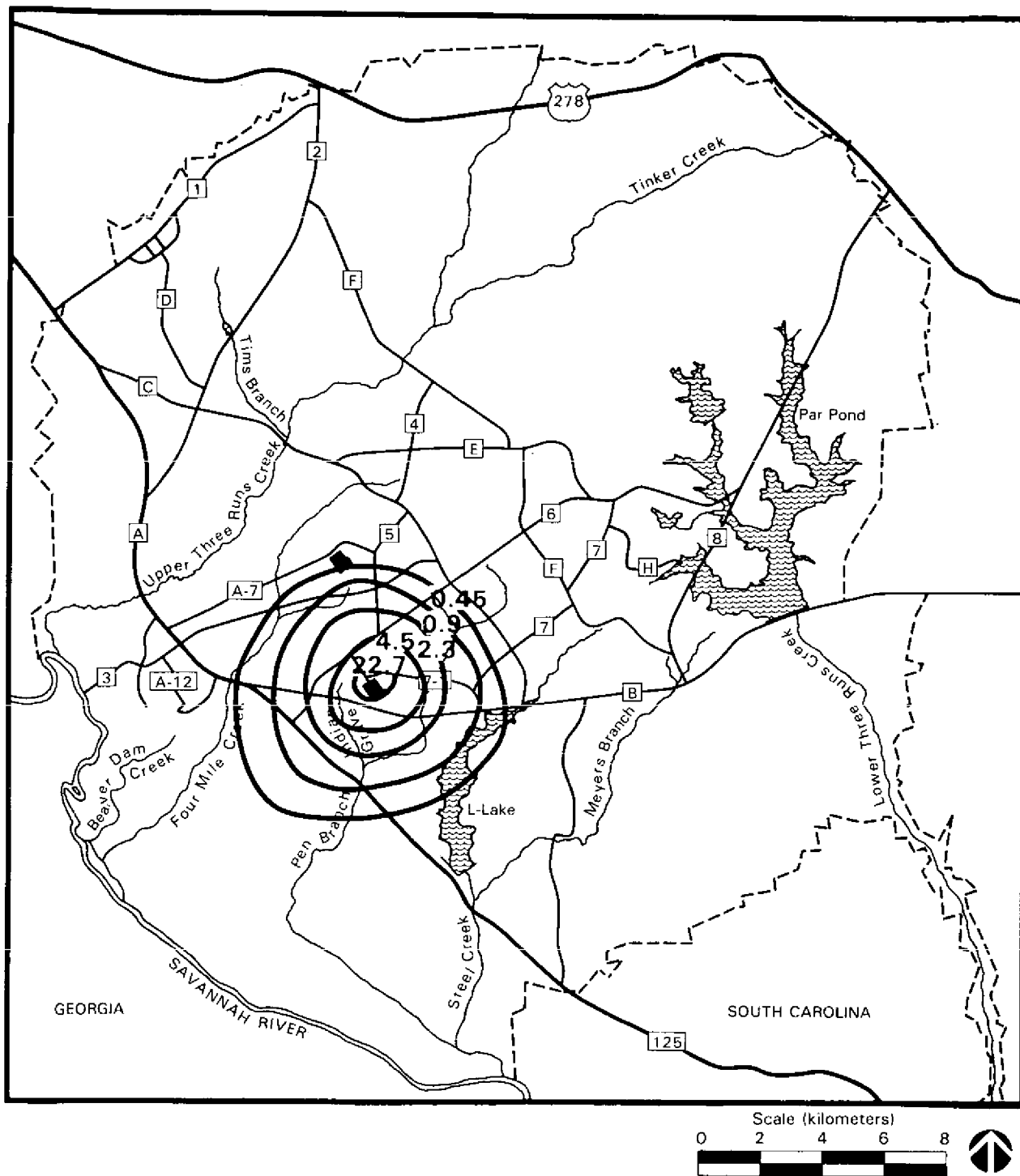
Air quality impacts from the operation of recirculating cooling towers at K-Reactor would be similar to those for a once-through cooling tower (Section 4.1.1.2).

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The calculated maximum annual-mean frequency of reduced ground-level visibility to less than 1000 meters would be approximately 2 hours per year, occurring about 8 kilometers south-southwest and about 10 kilometers northwest of the recirculating cooling towers. The maximum ice accumulation on horizontal surfaces would be no more than 1 millimeter beyond 0.8 kilometer in all directions from the towers. The maximum predicted ice thickness would be about 7 millimeters, occurring within 0.4 kilometer from the towers with a total frequency of 88 hours per winter season.

The maximum occurrence of visible plumes would be about 180 hours per year within 2 kilometers of the cooling towers in all directions.

Figure 4-2 shows isopleths of annual total solids deposition due to the operation of the K-Reactor recirculating towers. The maximum annual total-solids deposition would be about 22.7 kilograms per acre per year within 0.5 kilometer of the cooling towers and approximately 4.5 kilograms per acre per year within 1 kilometer from the cooling tower. At 2 kilometers, the predicted solids deposition is calculated to be about 2.2 kilograms per acre per year.



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Figure 4-2. K-Reactor Recirculating Tower, Total Solids Deposition, Kilograms/Acre-Year

Noise

BC-9 The operation of K-Reactor with recirculating cooling towers would cause increases in noise levels. Cooling-tower noise would consist of fan noise and falling water. Beyond approximately 152 meters from the cooling tower, average sound levels would be below 70 decibels. [Continuous exposure to 70 decibels or less has been determined to cause no loss of hearing (EPA, 1974).]

Ecology

Vegetation and Wetlands

BC-9 Vegetation near the recirculating cooling towers would not receive adverse
BC-19 impacts by cooling-tower drift. Operation of the towers would result in an
BD-3 estimated total solids deposition of about 2.2 kilograms per acre per year at
2 kilometers and about 22.7 kilograms per acre per year within 0.5 kilometer
of the cooling towers. Because these rates would be much less than the
critical values reported (see Section 4.1.1.2), no significant impacts on
vegetation should occur with this alternative.

K-Reactor operations have affected about 670 acres of wetlands in the floodplain and swamp (Du Pont, 1985b; Appendix F). Operation of recirculating cooling towers would reduce the rate of growth of the delta. Reestablishment of vegetation through the process of natural succession would occur for approximately 500 acres of wetland habitat along the creek corridor and swamp.

BC-3 To assist in ongoing consultations with FWS, a HEP analysis (Mackey et al., 1987) was conducted; it identified the value of habitat to be gained or lost with the recirculating cooling-tower alternative (see Section 4.6 and Appendix C for more details on HEP analysis).

Aquatic Habitat and Biota

BB-3 Balanced communities containing all indigenous species in all biotic
BC-4 categories should develop and remain in all natural portions of the Pen Branch ecosystem following implementation of a recirculating cooling-tower system for K-Reactor. Predicted maximum water temperatures in the immediate discharge area would not exceed 30°C and, therefore, would be below the maximum of 32.2°C required for Class B waters of the State. However, the other temperature criterion for Class B waters (maximum ΔT of 2.8°C) would be exceeded at times in the immediate discharge area and to a decreasing extent as far downstream as the Pen Branch delta (the beginning of the swamp; see Appendix B, Table B-5). Accordingly, a Section 316(a) Demonstration would be conducted for NPDES compliance after the cooling-tower system becomes operational. In addition to temperature mitigation, flow in the creek system would be reduced to levels typical of small streams in the SRP region; these levels would be conducive to recolonization by habitat formers, macroinvertebrates, and fish (Du Pont, 1987).

To compare and assess environmental impacts to the Pen Branch watershed before and after operation of the recirculating cooling-tower system, the stream system has been divided into three reaches based on the presence of three

distinct stream gradients: Reach 1 extends from the K-Reactor outlet down to SRP Road A, Reach 2 extends from SRP Road A to the mouth of the Pen Branch delta, and Reach 3 extends from the delta to the Savannah River.

Conditions for all biotic categories would be enhanced greatly following the implementation of this alternative in comparison to present conditions. Based on extensive data from Steel Creek, which had been impacted previously, recolonization of areas within the Pen Branch system that are presently uninhabitable because of excessive temperatures and flows would occur rapidly. Furthermore, an analysis of the temperature and flow requirements of the representative and important species indigenous to the creek system has revealed that these species should not be affected adversely by the slightly higher-than-ambient temperatures and lower flows resulting from K-Reactor operation following implementation of the recirculating cooling-tower system (Du Pont, 1987).

The Pen Branch system, which includes Pen Branch and Indian Grave Branch, is a low potential impact area for phytoplankton. The food base throughout this system consists of detrital material rather than phytoplankton, which is typical in lotic systems. Primary producers in the Pen Branch system consist primarily of periphyton and macrophytes (Du Pont, 1987).

Following implementation of a recirculating cooling-tower system, a zooplankton community would become established in the study area; this community would not be affected adversely by the operation of K-Reactor. This newly established community would provide food for the establishment of balanced indigenous macroinvertebrate and fish communities. The maximum predicted temperatures in the Pen Branch system would be within the range tolerated by most, if not all, indigenous species; accordingly, the heated discharge should cause no appreciable harm to the zooplankton community. The standing crop of zooplankton should be enhanced by the relatively slight temperature elevation and species composition and community structure should be similar to those of the Pen Branch system before SRP operation and to those of other natural streams in the region. The heated discharge is not likely to alter the standing crop, community structure, or seasonal periodicity of zooplankton in the farfield study area from those values typical of the receiving water body segment before reactor operation. Furthermore, cooling-tower blowdown flow would not constitute a lethal barrier to the free movement (drift) of zooplankton.

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The habitat-formers community should improve significantly with the addition of a recirculating cooling-tower system to K-Reactor. Following the cessation of L-Reactor thermal discharges in 1968 and the resultant reduction in both temperature and flow to Steel Creek, habitat formers along the stream corridor and on its delta began to improve immediately. Similarly, when temperature and flow to Beaver Dam Creek were reduced in the late 1970s, wetlands in the creek's delta in the Savannah River swamp began to improve. Both of these areas now have a mosaic of herbaceous persistent and nonpersistent marsh and scrub-shrub wetlands that directly and indirectly support diverse biological communities (Du Pont, 1987).

The heated discharge from recirculating cooling towers at K-Reactor would not result in any deterioration of the habitat-formers community, or in any appreciable harm to the balanced indigenous population in Pen Branch or the

Pen Branch delta region of the Savannah River swamp. Reach 1 (Indian Grave Branch) of the Pen Branch system is in a steeper, higher gradient stream valley; accordingly, macrophyte and other habitat formers would not be as likely to develop. Reaches 2 and 3 are at a lower gradient and are more open; thus, habitat-former communities would be more evident (Du Pont, 1987).

Following implementation of a recirculating cooling-tower system, reactor discharges would be reduced from approximately 11.3 cubic meters per second to about 1.1 cubic meters per second. This discharge, combined with the natural stream discharge, would result in a total discharge of 1.13 cubic meters per second. The reduced discharge would result in substantial reductions in stream width, depth, and water velocity in comparison to present conditions. Reduced water velocities would decrease the erosion rate of the stream channel in Reaches 1 and 2 and would be more conducive to the retention of logs and other organic debris in the stream channel, which provide structure for aquatic macroinvertebrates. Lower stream temperatures, coupled with reduced stream velocities, would permit the invasion of aquatic macrophytes into the stream channel, and would also permit the establishment of riparian vegetation in what is presently the high water channel of Pen Branch. Aquatic habitat in the delta (Reach 3) should differ somewhat from that in Reaches 1 and 2. At present, water flows through the delta in a series of shallow braided channels. With reduced discharge, most of the flow should follow the path of the original stream channel, but some water could flow through one or two of the deeper side channels that have been cut through the delta. This, coupled with the more gradual stream gradient of the delta, would probably result in lower velocities than would exist in Reaches 1 and 2. The delta area should provide prime habitat for many species of aquatic and semiaquatic macrophytes, which in turn would provide habitat for species of macroinvertebrates that prefer slow-moving streams and dense stands of macrophytes.

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At present, the macroinvertebrate community of the thermally impacted portion of Pen Branch is dominated by thermally tolerant chironomids and nematodes (Du Pont, 1987). Following implementation of the recirculating alternative, a diverse and productive community should develop. This newly established community would provide food necessary for the establishment of a balanced indigenous fish community.

The species composition of the Pen Branch corridor (Reaches 1 and 2) should be somewhat similar to that of the unimpacted headwaters portion of Pen Branch, although differences would exist due to a more open canopy and to greater stream discharge volumes from K-Reactor operations. Increased light availability would result in a system that is more autochthonous. Thus, macroinvertebrate species that utilize periphyton or macrophytes as food would be more abundant. Scrapers (such as snails and beetles), as well as collector-gatherers and collector-filterers (such as mayflies) that feed on particulate organic matter, should be more abundant downstream from the reactor outfall. As macrophyte beds become established, macroinvertebrate species that are commonly associated with macrophyte beds, such as scuds, water mites, beetles, and aquatic bugs (Hemiptera) would increase in abundance. Numerically, however, the chironomids should continue to dominate the macroinvertebrate community of the Pen Branch corridor, as they do in most southeastern streams. The dominant chironomid taxa, however, would shift, with the more thermally tolerant species being replaced by other species that are less thermally tolerant (Du Pont, 1987).

The macroinvertebrate community of Reach 3 would differ from that of Reaches 1 and 2 due to habitat differences (i.e., current velocity and stream sediment) that occur where the stream enters the delta. The macroinvertebrate community of Reach 3, through succession, eventually should resemble that of the recovering Steel Creek delta. Species expected to be most abundant in the delta would include snails, scuds, water mites, many species of odonates, coleopterans, hemipterans, and several chironomid genera. The chironomids should dominate numerically, although other groups, such as snails and amphipods, could be more important with respect to biomass.

A recirculating cooling-tower system would improve the thermal regime of Pen Branch over existing conditions. With this system, the maximum predicted summer temperatures in the three reaches of the stream would be 30°C, 29°C, and 29°C, respectively (see Appendix B, Table B-5). These temperatures are within the range tolerated by most, if not all, indigenous species, because ambient summer water temperatures in many southeastern streams equal or exceed these values. Maximum average monthly ΔT for the three reaches would be 6°C, 4°C, and 5°C, respectively. Although the increases in temperatures could result in the earlier emergence of some species, no significant adverse impacts should occur, and the potential for cold shock would not exist during reactor outages in the winter. Thus, the cooling-tower blowdown should cause no appreciable harm to the macroinvertebrate community of Pen Branch.

However, the standing crop of macroinvertebrates in Pen Branch should be enhanced by the relatively slight elevation in temperature, due in part to an expected increase in the standing crop of periphyton and heterotrophs, which would provide more food for many species of macroinvertebrates. In addition, the slightly elevated temperatures could permit multivoltine species of insects (those that complete more than one life cycle per year) to produce one or more additional generations per year, thereby increasing the net annual production of the macroinvertebrate community.

The cooling-tower blowdown flow should not interfere with the drift or upstream movement of macroinvertebrates, because the predicted maximum temperature of the flow is less than the upper thermal limits of most macroinvertebrate species indigenous to the area. No farfield impacts should occur, because the water is essentially at ambient temperature by the time it enters Steel Creek.

The fish community in upper Pen Branch above K-Reactor should not change substantially from present conditions because the fish communities in the upper reaches of SRP tributary streams appear to be stable and not affected significantly by reactor operations (Du Pont, 1987). One major difference caused by cooling-tower operation could enhance the fish community in this portion of the stream system. Water temperatures at the confluence of Indian Grave Branch and Pen Branch would never exceed 30°C and the average monthly ΔT would not exceed 6°C. Thus, water temperature should no longer inhibit the movement of fish between the Savannah River and the headwaters of Pen Branch. This could result in additional spawning in the upper reaches and would provide a pathway for immature fishes spawned in the upper reaches to contribute to the populations in Reaches 1, 2, and 3 of Pen Branch below K-Reactor and in the Savannah River.

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Following implementation of the recirculating cooling-tower alternative, a temperature-restricted zone of passage in Reach 1 should no longer exist. Flow would be reduced during reactor operation because cooling water discharge would decline from about 11.3 cubic meters per second to about 1 cubic meter per second. These changes would allow fish to reinvade this section of the stream system, and would provide spawning and nursery areas for some species.

Maximum absolute temperatures in Reach 2 would not exceed 29°C and average monthly ΔT values would not exceed 4°C throughout the year. Together with reduced flow, this factor would allow indigenous fish species to inhabit Reach 2. Some areas of Reach 2 should be suitable for spawning, thereby increasing fish populations. Furthermore, the addition of slightly heated and relatively nutrient-rich Savannah River water to Pen Branch via the cooling-tower blowdown could increase primary and secondary production in this area. The result would be an enhancement of fish growth in this portion of the creek in comparison to expected fish growth under ambient conditions.

BB-3 All of Reach 3 should be suitable habitat for all indigenous fishes of the Pen
BC-9 Branch system. Maximum temperatures would not exceed 29°C and average monthly ΔT would not exceed 5°C. Reactor operation should have no adverse impact on reproduction. Growth should be enhanced by the increased productivity resulting from the slight temperature elevation and nutrient loading from Savannah River water pumped through the system. The areal extent of aquatic habitat should be reduced from the present situation because of the reduced flows (present discharge of 11.3 cubic meters per second versus cooling-tower blowdown plus auxiliary system flows of 1 cubic meter per second). However, the system would more closely resemble ambient conditions.

The absolute maximum predicted water temperature at the cooling-tower discharge point would be 30°C (see Appendix B, Table B-5) and the maximum predicted average monthly temperature would be 27°C. In contrast, the upper incipient lethal temperatures for representative and important species (largemouth bass, bluegill, and catfish) are in the mid- to upper 30s°C. The cooling-tower system would comply with the temperature shock limits proposed by EPA for the protection of all warm-water fishes (EPA, 1977). Laboratory studies have shown these limits to be protective of the temperature tolerance limits of largemouth bass, bluegill, and channel catfish (Wilde, 1987; Storms, 1985). Reproductive success and growth of all indigenous fish species would be improved over present conditions by this mitigation plan; growth should be enhanced even above potential ambient temperature levels because the slight warming from the tower blowdown would result in optimal growth temperatures for more of the year than with ambient conditions. Maximal absolute temperatures (30°C) and maximum average monthly ΔT values (6°C) should not block fish migration. Thus, the entire Pen Branch system would be available for fish habitation; the free movement of fishes between the headwaters of Pen Branch and the Savannah River should not be inhibited by K-Reactor operations at any time during the year. The thermal discharge flow would not block fish migration or exclude fish from any part of the ecosystem.

Entrainment and Impingement

BD-5 The operation of recirculating cooling towers for K-Reactor would reduce the requirements for cooling water withdrawal from about 11.3 to about 1.6 cubic

meters per second. The rates of entrainment of fish eggs and larvae into a cooling water system are directly proportional to the flow rate through that system. Because the flow requirements of recirculating towers would be about 14.5 percent of current levels, entrainment losses would be reduced proportionally. The estimated annual entrainment losses of fish larvae from operating recirculating cooling towers for K-Reactor would decline from an average of about 8.8×10^6 with current operations to about 1.3×10^6 individuals; annual losses of fish eggs would decline from an average of about 4.6×10^6 to about 6.7×10^5 individuals (DOE, 1987). The taxonomic groups benefiting from these reductions would be the clupeids (principally the American shad), the centrarchids, and the cyprinids.

The rate at which fish are impinged on the SRP intake screens is related not only to intake flow rates, but also to such factors as river water level, water temperature, and the density of fish species in the intake canal (Du Pont, 1985b). Assuming that the rates of impingement are proportional to intake flow rates, the impingement loss with a recirculating cooling-tower system would be about 14.5 percent of current levels. The 1983-1985 investigations conducted at the 1G and 3G intakes projected the impingement of 2942 annually on the screens as a result of K-Reactor operation (DOE, 1987). The operation of recirculating cooling towers would reduce this number to about 427 individuals annually. This reduction would most benefit the bluespotted sunfish, threadfin shad, gizzard shad, redbreast sunfish, and warmouth, which are the species now impinged in greatest numbers at the intakes.

BD-5

Threatened and Endangered Species

Implementation of this alternative would result in a reduction of the effluent discharge from 11.3 to about 1 cubic meter per second; this would allow the stream channel to revert approximately to its original width, and would allow fish and invertebrates to inhabit the stream channel. It would also create foraging habitat for the endangered wood stork and provide potential habitat for the American alligator. Because of the reduced flow rate, nests, eggs, and hibernation sites of the American alligator should not be impacted.

BB-3

Formal consultations were held between DOE and the FWS to comply with the Endangered Species Act of 1973. Based on these consultations, the FWS issued a biological opinion that the preferred alternative cooling systems should have no effect on endangered and threatened species (Parker, 1986; Henry, 1986).

TC

Radiological Releases

Appendix G contains details of the dose assessment methodology and parameters; it also contains tables that list specific organ doses by pathway and age-group.

Remobilization of Radionuclides

The operation of the recirculating cooling towers would reduce the flow rate of cooling water in Indian Grave Branch and Pen Branch and, therefore, would decrease the amount of radionuclides being remobilized from the creek bed and

BC-22

transported to the Savannah River. The primary radionuclide contained in Pen Branch sediments is cesium-137 (Appendix D). The reduced flow in Pen Branch would result in a decrease of about 0.12 curie of cesium-137 released annually to the Savannah River.

Maximum Individual Dose - The individual who would experience the greatest change in dose from cesium remobilization is assumed to live near the Savannah River downstream from the SRP. This individual is assumed to use river water regularly for drinking, to consume fish from the river, and to experience external exposures from shoreline activities. This individual is also assumed to drink more water and eat more fish than an average person.

Table 4-8 lists the changes in effective-whole-body and most-affected-organ (gonads) doses to the maximally exposed individual resulting from the decrease in cesium-137 released to the Savannah River.

Table 4-8. Decrease in Doses to Maximally Exposed Individual Resulting from Cesium Redistribution Associated with K-Reactor Recirculating Cooling Towers

Age group	<u>Incremental dose reduction (mrem/yr)</u>	
	Effective whole body	Gonads ^a
Adult	6.88×10^{-2}	6.88×10^{-2}
Teen	5.27×10^{-2}	5.27×10^{-2}
Child	2.29×10^{-2}	2.29×10^{-2}
Infant	2.21×10^{-4}	2.21×10^{-4}

a. Dose to gonads is directly comparable to soft-tissue doses resulting from tritium, because tritium imparts an equal dose to all soft tissues (i.e., all organs except bone).

Population Dose - Table 4-9 lists the decreases in the collective doses delivered to the affected population groups.

Tritium Releases

The following sections discuss changes in the doses to the maximally exposed individual at the SRP boundary and to offsite population groups (based on year 2000 projections) that are attributable to changes in atmospheric and liquid releases to Indian Grave Branch and Pen Branch of tritium resulting from the operation of recirculating cooling towers.

Atmospheric Releases - The amount of tritium released annually to the atmosphere is expected to increase by 425 curies (about 0.1 percent of total SRP releases of tritium to the atmosphere) as a result of evaporation of

Table 4-9. Decrease in Collective Effective Whole-Body Dose Resulting from Cesium Redistribution Associated with K-Reactor Recirculating Cooling Towers

Population group	Incremental collective dose reduction (person-rem/yr)
80-km population	1.91×10^{-1}
Beaufort-Jasper	1.05×10^{-2}
Port Wentworth	3.81×10^{-2}
Total	2.40×10^{-1}

BC-22

cooling water. This would increase the atmospheric dose commitments of the regional population and the maximally exposed individual. Changes in dose commitments resulting from the increased release of atmospheric tritium are summarized below.

TE

Maximum Individual Dose - The individual who would receive the highest effective whole-body dose from atmospheric releases associated with this cooling alternative is at the same location described in Section 4.1.1.2.

BC-22

Table 4-10 summarizes the annual increases in soft-tissue and effective whole-body doses received by the maximally exposed individual due to the atmospheric release of tritium.

Table 4-10. Increase in Annual Dose to Maximally Exposed Individual Resulting from Atmospheric Releases of Tritium from K-Reactor Recirculating Cooling Towers

Age group	Incremental dose increase (mrem/yr)	
	Effective whole body	All soft tissues ^a
Adult	8.92×10^{-4}	1.05×10^{-3}
Teen	9.65×10^{-4}	1.13×10^{-3}
Child	6.69×10^{-4}	7.87×10^{-4}
Infant	1.98×10^{-4}	2.32×10^{-4}

BC-22

- a. Tritium imparts an equal dose to all soft tissues (i.e., all organs except bone) that is 18 percent higher than the effective whole-body dose.

Population Dose - Collective doses resulting from atmospheric releases associated with this cooling alternative are calculated for the population within 80 kilometers of the SRP. The annual collective effective whole-body dose to this population would increase by 4.22×10^{-2} person-rem as a result of the increase in tritium released to the atmosphere.

Liquid Releases - The operation of this cooling alternative would reduce the amount of tritium released to the stream by 425 curies per year (about 1 percent of the total SRP releases of tritium to streams) as a result of evaporation of cooling water. Doses associated with the change in liquid releases are discussed below for both the population and the maximally exposed individual.

Maximum Individual Dose - The hypothetical individual who would experience the greatest change in dose from liquid effluents is the same as that described earlier in Section 4.1.1.2.

Table 4-11 summarizes the annual decrease in soft-tissue and effective whole-body doses received by the maximally exposed individual due to a decrease in the liquid release of tritium.

Table 4-11. Decrease in Annual Dose to Maximally Exposed Individual Resulting from a Decrease in Liquid Releases of Tritium from K-Reactor Recirculating Cooling Towers

Age group	Incremental dose reduction (mrem/yr)	
	Effective whole-body	All soft tissues ^a
Adult	1.85×10^{-3}	2.18×10^{-3}
Teen	1.31×10^{-3}	1.53×10^{-3}
Child	1.27×10^{-3}	1.50×10^{-3}
Infant	8.06×10^{-4}	9.48×10^{-4}

a. Tritium imparts an equal dose to all soft tissues (i.e., all organs except bone) that is 18 percent higher than the effective whole-body dose.

Population Dose - The decrease in the collective effective whole-body dose within 80 kilometers of the Savannah River Plant from reduced liquid releases of tritium associated with this cooling alternative would be 2.09×10^{-4} person-rem per year (Table 4-12).

The decrease in the collective effective whole-body dose delivered to the Beaufort-Jasper and Port Wentworth population groups who use the Savannah River as a source of potable water (about 317,000) from tritium in drinking water would be 2.78×10^{-1} person-rem per year, as presented in Table 4-12.

Table 4-12. Decrease in Collective Effective Whole-Body Dose Resulting from Liquid Releases of Tritium from K-Reactor Recirculating Cooling Towers

Population group	Incremental collective dose reduction (person-rem/ea. yr)
80-km radius	2.09×10^{-4}
Beaufort-Jasper	9.58×10^{-2}
Port Wentworth	1.82×10^{-1}
Total	2.78×10^{-1}

Overall Changes in Offsite Doses

Table 4-13 summarizes changes in the effective whole-body and the most-affected-organ doses received by the maximally exposed individual resulting from the operation of this cooling alternative. Table 4-14 lists changes in the annual collective effective whole-body dose.

BC-22

The average background total-body dose to an individual living in the vicinity of the Savannah River Plant is 93 millirem per year. By extrapolation, the annual collective total-body dose to the 80-kilometer population is 79,200 person-rem; to the Port Wentworth water users, it is 18,600 person-rem; and to the Beaufort-Jasper water users, 10,900 person-rem. This cooling alternative would reduce the annual effective whole-body dose to the maximally exposed adult by 6.98×10^{-2} millirem, and the collective effective whole-body dose to the 80-kilometer population and the Port Wentworth and Beaufort-Jasper water users by 1.49×10^{-1} , 2.20×10^{-1} , and 1.06×10^{-1} person-rem per year, respectively. These changes are very small in comparison to year-to-year variations in natural background radiation.

BC-22

Present SRP operations result in an effective whole-body dose of 5.18×10^{-2} millirem per year to the maximally exposed adult from tritium releases to the Savannah River from Indian Grave Branch and Pen Branch. This alternative would reduce the liquid tritium dose by 1.85×10^{-3} millirem per year and increase the atmospheric tritium dose by 8.92×10^{-4} millirem per year, resulting in an overall reduction of 9.58×10^{-4} millirem per year. Similarly, the current effective whole-body dose to the maximally exposed adult from cesium releases is 8.03×10^{-2} millirem per year. This alternative would reduce this dose by 6.88×10^{-2} millirem per year.

Health Effects

BC-22

Using the cancer and genetic damage risk estimators discussed above and the organ doses presented in Appendix G, the population within 80 kilometers of the Savannah River Plant could experience a decrease of 1.11×10^{-5} cancer

Table 4-13. Changes in Effective Whole-Body and Gonadal Doses Received by Maximally Exposed Individual Resulting from Operation of K-Reactor Recirculating Cooling Towers (millirem per year)

Source of exposure	Adult	Teen	Child	Infant
EFFECTIVE WHOLE-BODY DOSE INCREMENT				
Atmospheric tritium releases ^a	8.92×10^{-4}	9.65×10^{-4}	6.69×10^{-4}	1.98×10^{-4}
Liquid tritium releases ^a	$-1.85 \times 10^{-3(b)}$	-1.31×10^{-3}	-1.27×10^{-3}	-8.06×10^{-4}
Cesium transport	-6.88×10^{-2}	-5.27×10^{-2}	-2.29×10^{-2}	-2.21×10^{-4}
Net dose change	-6.98×10^{-2}	-5.30×10^{-2}	-2.35×10^{-2}	-8.29×10^{-4}
GONADAL DOSE INCREMENT ^c				
Atmospheric tritium releases ^a	1.05×10^{-3}	1.13×10^{-3}	7.87×10^{-4}	2.32×10^{-4}
Liquid tritium releases ^a	-2.18×10^{-3}	-1.53×10^{-3}	-1.50×10^{-3}	-9.48×10^{-4}
Cesium transport	-6.88×10^{-2}	-5.27×10^{-2}	-2.29×10^{-2}	-2.21×10^{-4}
Net dose change	-6.99×10^{-2}	-5.31×10^{-2}	-2.36×10^{-2}	-9.37×10^{-4}

a. Tritium imparts a dose to soft tissues about 18 percent higher than to the effective whole body.

b. Negative sign preceding number denotes a decrease in dose.

c. Gonadal dose is directly comparable to soft-tissue doses resulting from tritium, because tritium imparts an equal dose to all soft tissues (i.e., all organs except bone).

BC-22 fatality and 3.66×10^{-5} genetic disorder per year from the operation of this system. The populations at Beaufort-Jasper and Port Wentworth downstream from the SRP could experience decreases of 3.67×10^{-5} fatal cancer and 9.65×10^{-5} genetic disorder per year. Table 4-15 summarizes this information.

4.1.3 NO ACTION - EXISTING SYSTEM

The no-action alternative for K-Reactor would maintain the existing once-through cooling water system that withdraws water from the Savannah River and discharges it into Pen Branch via Indian Grave Branch. Chapter 3 and Appendix C describe the environmental baseline conditions that are associated with this system. This section summarizes the major environmental impacts of the existing system.

Table 4-14. Changes in Collective Effective Whole-Body Dose Resulting from Operation of K-Reactor Recirculating Cooling Towers (person-rem per year)

Source of exposure	80-kilometer population	Beaufort Jasper	Port Wentworth	Total
Atmospheric tritium releases	4.22×10^{-2}	-	-	4.22×10^{-2}
Liquid tritium releases	$-2.09 \times 10^{-4(a)}$	-9.58×10^{-2}	-1.82×10^{-1}	-2.78×10^{-1}
Cesium transport	-1.91×10^{-1}	-1.05×10^{-2}	-3.81×10^{-2}	-2.40×10^{-1}
Net dose change	-1.49×10^{-1}	-1.06×10^{-1}	-2.20×10^{-1}	-4.76×10^{-1}

a. Negative sign denotes a decrease in dose.

BC-22

Table 4-15. Changes in Annual Health Effects

Population group	Genetic disorders	Fatal cancers
80-kilometer radius	-3.66×10^{-5}	-1.11×10^{-5}
Beaufort-Jasper	-3.17×10^{-5}	-1.21×10^{-5}
Port Wentworth	-6.48×10^{-5}	-2.46×10^{-5}
Total	-1.33×10^{-4}	-4.78×10^{-5}

4.1.3.1 Water Quality and Hydrology

The average flow in Pen Branch when K-Reactor is operating would continue to be about 11.3 cubic meters per second in excess of the natural stream flow of 0.03 cubic meter per second.

BC-22

Maximum water temperatures of the discharge would reach 73°C during extreme summer conditions with water temperatures at the delta about 52°C; ambient stream temperatures would be 33°C. Under average winter conditions, temperatures along Pen Branch would range from 66°C at the discharge point to 43°C in the delta. These conditions would be present only when K-Reactor was in operation. The continuation of the existing cooling water discharge from K-Reactor would not comply with South Carolina Class B water classification standards.

Dissolved oxygen concentrations would continue to be depressed in Indian Grave Branch and Pen Branch during reactor operations because of the elevated water

temperatures. Concentrations in Indian Grave Branch just below the reactor discharge point would average about 5.4 milligrams per liter. The mean concentration in Pen Branch would be about 5.7 milligrams per liter, with a range of 3.3 to 11.1 milligrams per liter. Values occasionally would fall below minimum state Class B water classification standards (5 milligrams per liter) in both streams.

Generally, nutrient concentrations in the thermal reaches of the two streams would continue to be higher than in nonthermal reaches of the streams, due to inputs of nutrient-rich Savannah River water because of the addition of higher nutrient content Savannah River water.

4.1.3.2 Ecology and Wetlands

BB-3
BC-19

The aquatic and terrestrial communities in and along Indian Grave Branch and Pen Branch would continue to be influenced largely by the heated discharges from K-Reactor. Blue-green algal mats would continue to cover much of the sand and silt substrate in Pen Branch. Riparian vegetation would include sedges, grasses, wax myrtle, and buttonbush, while duckweed would be abundant in the many side pools and channels. The delta region of the stream would be characterized by an open and closed canopy of living and dead bald cypress and tupelo. A total of about 670 acres of wetlands would continue to be affected in the Pen Branch floodplain and delta; canopy losses would continue at the rate of about 26 acres per year.

Most aquatic invertebrate species would be absent from Indian Grave Branch and Pen Branch during reactor operations (DOE, 1984). Benthic invertebrate species would be more abundant in the delta area than in the main channel of Pen Branch (Du Pont, 1985b; Appendix C). Resident populations of fish (sunfish, shiners, bullheads, etc.) would be present in the upper reaches of Pen Branch above the confluence with Indian Grave Branch; some spawning could continue (DOE, 1984). No fish would be present in the reaches of the creeks below K-Reactor during discharges of heated effluents; in addition, population numbers would be smaller in the swamp/delta area during reactor operation. Fish would be found in cooler refuge areas along the shoreline of the main thermal channels. The heated discharge water would cause no impact to fish populations in the Savannah River. Ichthyoplankton would continue to be absent or at greatly reduced densities in Pen Branch. In the delta, the dominant ichthyoplankton would be mosquitofish, which are found principally in the cooler refuge areas (DOE, 1984).

TE

Waterfowl use of Pen Branch would continue to be associated primarily with the delta and slough areas where the creek empties into the swamp. These areas, as well as much of the Savannah River swamp near the Plant, would continue to provide foraging habitat for migratory species during fall and winter.

4.1.3.3 Entrainment and Impingement

BB-3

No action would result in the continued loss of an average 8.8×10^6 fish larvae and 4.6×10^6 fish eggs each year (DOE, 1987). The principal taxa entrained as larvae would be expected to be the clupeids (shad, herring, etc.), the centrarchs (crappie, sunfish, etc.), and the cyprinids (carp, etc.). The eggs of the American shad and the striped bass would be entrained most often.

The estimated average impingement on the intake screens of the 1G and 3G pumphouses (which provide cooling water to K- and C-Reactors) would be about 5885 fish per year, half (2942 fish) of which would be attributed to K-Reactor, based on 1983-1985 investigations (DOE, 1987). The principal species would be bluespotted sunfish and threadfin shad; gizzard shad, redbreast sunfish, and warmouth would also be impinged frequently.

BB-3
BD-5

4.1.3.4 Threatened and Endangered Species

Although temperatures in the thermal affected areas of Indian Grave Branch and Pen Branch would exceed the critical thermal maximum for the American alligator, a few individuals could occupy cooler refuges along the margins of the creeks and delta (DOE, 1984). The wood stork should not inhabit Pen Branch during reactor operations because the habitat would not be suitable for foraging; however, wood stork have been observed during periods of extended reactor shutdowns.

BB-3

4.2 ALTERNATIVES FOR C-REACTOR

The cooling water alternatives for C-Reactor are identical to those for K-Reactor (i.e., a once-through cooling tower, recirculating cooling towers, and no action). In many instances, the expected environmental consequences resulting from construction and operation of the alternatives are identical or similar. The following sections describe expected environmental consequences of the alternatives for C-Reactor that differ from those expected for K-Reactor.

TE

4.2.1 ONCE-THROUGH COOLING TOWER

As discussed for K-Reactor, design evaluations and studies were performed to optimize the performance and achieve cost savings in the construction and operation of once-through cooling towers without introducing major changes in the nature or magnitude of environmental impacts. The following discussion emphasizes differences between the construction and operational impacts of cooling-water alternatives for K- and C-Reactors.

TC

TE

4.2.1.1 Construction Impacts

Socioeconomics

The construction of a once-through cooling tower for C-Reactor would be accomplished in approximately 36 months, after a 9-month lead design period. Construction could involve a combined workforce for the towers in both K- and C-Areas. The estimated peak construction work for C-Reactor alone is 200 persons.

TC

TE

Historic and Archaeological Resources

The most recent archaeological and historic resources survey of the Four Mile Creek watershed area was conducted from May through August 1984, as described in Appendix E; this survey located 25 sites in the watershed. The implementation of the once-through cooling-tower alternative would disturb

only one site (38BR548) in the Four Mile Creek area. Site 38BR548 is a small prehistoric lithic and ceramic scatter located on a terrace edge adjacent to the bank of the northern branch of Four Mile Creek. No impact mitigation has been recommended for this site, because the potential yield of additional research information is negligible.

Water Quality

The water quality impacts from construction of a once-through cooling tower for C-Reactor would be the same as those described for K-Reactor (Section 4.1.1.1).

Ecology

TC

For a once-through cooling tower with gravity feed, approximately 35 acres of existing habitat would be disturbed by construction. Most of the affected habitat lies north of SRP Road 3 and is characterized by dense shrub, intermixed with pine 4 meters tall. The area south of SRP Road 3 contains mixed pine and hardwood forest with a sparse understory. No effects are expected on vegetation outside the immediate construction area. The effluent canal from the cooling tower to Castor Creek would require the removal of about 0.5 acre of bottomland hardwoods consisting mainly of sweet gum and yellow poplar.

The potential effects on fish and wildlife from the construction of a once-through cooling-tower system would be similar to those associated with K-Reactor (see "Ecology" in Section 4.1.1.1).

Radiological Releases

During the construction of the once-through cooling tower, there would be no changes in the atmospheric and liquid releases of radionuclides. Reactor operation and the flow rate in Four Mile Creek would remain the same. There would be no changes in reactor releases or remobilization of radionuclides from the stream bed and, consequently, radiation doses to the offsite population would not change.

TC

As discussed in Section 4.1.1.1, construction personnel for the tower would experience levels of radiation slightly elevated above background from the operation of Plant facilities, which is estimated to be approximately 20 millirem per year.

Other Construction Impacts

Other construction impacts would be similar to those described for K-Reactor (i.e., air quality, noise, solid waste, and onsite construction personnel exposure to radioactive releases). All applicable atmospheric emission standards would be met during construction, solid waste generated from construction would be disposed of in an approved manner, and fueling and maintenance of construction equipment would be performed under controlled conditions to minimize spills.

4.2.1.2 Operational Impacts

Socioeconomics

The small number of additional workers (four) associated with the operation of the once-through cooling tower at C-Reactor would not cause any noticeable socioeconomic impacts in the study area.

Historic and Archeological Resources

The operation of a once-through cooling tower for C-Reactor would not impact any historic or archaeological resources. Anticipated flows in Four Mile Creek would be nearly the same as those at present, with little change in stream morphology. An archaeological and historic resources survey in the Four Mile Creek watershed area located no significant sites requiring impact mitigation (Appendix E).

Water Quality and Hydrology

The once-through cooling tower would impact water quality in Castor and Four Mile Creeks and the Savannah River swamp primarily by lowering instream temperatures to meet the State of South Carolina's Class B water classification standard of 32.2°C. Water temperatures from the tower discharge would be at a maximum of about 32°C (Table 2-4) under extreme summer conditions. During an average summer (June-August), the water discharged from the tower would be about 29°C, which compares to an ambient creek temperature of 25°C.

TC

The cooling tower would be designed and operated in a manner that would meet the Maximum Weekly Average Temperature (MWAT) criteria (EPA, 1977) to minimize thermal shock of fish that could occur with a reactor outage (Muhlbaier, 1986). Because expected instream temperatures during winter and spring average conditions would be raised more than 2.8°C above ambient due to the operation of the cooling-tower system, a Section 316(a) Demonstration study would be performed after construction and submitted to SCDHEC; this study would demonstrate if effluent temperature conditions would ensure the protection and propagation of a balanced indigenous population of fish and wildlife in and on the waters affected by the discharge.

BB-3

Cooling water discharges from the once-through cooling tower would raise dissolved oxygen concentrations and lower total suspended solids in the same manner as that described for the K-Reactor once-through cooling tower. Effluents discharged would be similar to those associated with the present once-through system except that nonvolatile constituents would be slightly more concentrated due to evaporation losses of water in the tower. Chlorine biocide would be added to reactor cooling water to prevent biofouling of the cooling towers; it would be neutralized with sodium sulfite prior to discharge to Castor Creek. As discussed for K-Reactor, no adverse effects are expected on aquatic biota or water quality from these additions. Discharges would meet all NPDES permit limits. When C-Reactor is not operating, the concentrations of chemical pollutants in Four Mile Creek would not change appreciably in the absence of the cooling water discharge because the stream meets state Class B water classification standards under these conditions (see Section 3.3.3; Du Pont, 1985b).

BB-1
BB-2

BC-10 | Operation of the once-through cooling-tower system would result in the same small changes in the hydrology of Four Mile Creek and the associated swamp as those described for K-Reactor. The changes would not adversely impact the stream system because the flow would be reduced only about 0.8 cubic meter per second when the reactor is operating. When C-Reactor is not operating, the stream flow in Four Mile Creek would continue to be reduced from 11.3 to 0.6 cubic meter per second, on average.

Air Quality

TE | The operation of a once-through natural-draft cooling tower at C-Reactor could result in the formation of ground-level fog, ice, elevated visible plumes, and total-solids (drift) deposition on the ground. As discussed in Section 4.1.1.2 and Appendix B, a computer model (Fisher, 1974) was used to predict the atmospheric effects of cooling-tower operation.

TC | The predicted maximum annual mean frequency of reduced ground-level visibility, maximum ice accumulation on horizontal surfaces, and the calculated maximum occurrence of visible plumes aloft (primarily on SRP Road 3) would be essentially the same as those presented for K-Reactor in Section 4.1.1.2. The calculated maximum occurrence would be 50 hours per year within 1.5 kilometers of the cooling tower, primarily on SRP Roads A-7, 3, and 5.

TC | The calculated maximum annual total-solids deposition within 2 kilometers of the cooling tower would be about 0.5 kilogram per acre per year, the same as that for K-Reactor.

Noise

TC | The operation of a once-through natural-draft cooling tower with gravity feed at C-Reactor would cause increases in noise levels. Cooling-tower noise would come from falling water. Beyond approximately 152 meters from the cooling tower, average sound levels would be below 70 decibels. [Continuous exposure to 70 decibels or less has been determined to cause no loss of hearing (EPA, 1974).] At the nearest offsite area, noise from C-Reactor activities would not be detectable.

Ecology

Vegetation and Wetlands

TC | Deposition of drift from a once-through cooling tower for C-Reactor would be similar to that projected for K-Reactor (about 0.5 kilogram per acre per year within 2 kilometers). No adverse impacts on vegetation are expected because maximum deposition rates are well below critical values.

The most significant positive impact on vegetation from the operation of a once-through cooling tower would be a reduction in the loss of wetland habitat due to thermal discharges; losses due to sedimentation would continue. However, sedimentation rates in the delta and the total suspended solids discharged to Four Mile Creek would both be reduced. Portions of the delta would revegetate when the water temperature was reduced. There would be limited reestablishment of upstream wetland communities along Four Mile Creek

because the stream would still be subject to variable flows. From 1955 through 1984, about 1147 acres of wetlands were affected in the Four Mile Creek floodplain and swamp due to thermal discharges and flooding (Du Pont, 1985b, 1987; Appendix F), with an average loss of about 28 acres per year in the swamp. The operation of a once-through cooling tower would eliminate both additional losses in the stream corridor and thermal effects - one of the three major factors (the others are flooding from reactor operation and river flooding) - responsible for continuing swamp canopy loss (Du Pont, 1985b, 1987). The reduction in effluent temperatures would, therefore, have a beneficial impact on wetland communities by significantly reducing wetland loss.

The operation of the gravity-feed tower would result in about 1.5 kilometers of Castor Creek upstream of the discharge reverting to natural stream conditions, because the tower discharge would be located about 1.5 kilometers downstream from C-Reactor.

To assist in ongoing consultations with FWS, a HEP analysis (Mackey et al., 1987) was conducted; it identified the value of habitat to be gained or lost with the once-through cooling-tower alternative (see Section 4.6 and Appendix C for more details on HEP analysis).

BC-3

Aquatic Habitat and Biota

The environmental consequences resulting from the operation of a once-through cooling-tower system on aquatic habitat and biota in Four Mile Creek and Castor Creek would be similar to those described for K-Reactor with this alternative.

TC

Entrainment and Impingement

The estimated numbers of ichthyoplankton entrained and fish impinged from the operation of the once-through cooling-tower system for C-Reactor would be the same as those described for K-Reactor, because the two reactors draw cooling water from the same sources (1G and 3G canals) and would require the same circulating water volume.

Threatened and Endangered Species

TC

The operation of the once-through cooling-tower system would not impact the habitat of the endangered red-cockaded woodpecker. No active or inactive red-cockaded woodpecker colony has been located in the Four Mile Creek area.

The first sighting of an active bald eagle nest on the SRP occurred on June 5, 1986. The nest is below Par Pond dam in the Lower Three Runs Creek drainage basin. Because of the nest location and due to the implementation of management practices in accordance with the guidelines of the 1984 bald eagle recovery plan, the FWS issued a finding of "no effect" for this species in 1986 (Henry, 1986).

TC

The American alligator occurs on the SRP site in both flowing waters and lake environments. Mildly thermal water appears to attract alligators,

particularly during the winter. Under current reactor operating conditions, the water temperature in Four Mile Creek exceeds the critical thermal maximum (38°C) for American alligators, thus precluding their presence (Sires, 1984). The operation of a once-through cooling-tower system would lower the temperature in the reaches of Four Mile Creek well below the alligator's critical thermal maximum temperature, thus improving the habitat for this species. However, fluctuating water levels and flow rate could inundate the nests, eggs, and hibernation sites.

As discussed for K-Reactor, the operation of a once-through cooling tower for C-Reactor would produce no adverse impacts on the shortnose sturgeon.

BB-3 Based on studies of the endangered wood stork since 1983, this species forages in the SRP swamps and streams (Meyers, 1984; Coulter, 1986). In 1985, most wood storks foraged in the Four Mile Creek delta and in the swamp between Pen Branch and the Four Mile Creek delta following shutdown of C-Reactor in June (Du Pont, 1987). However, low fish densities, high water temperatures, and increased water depths from existing reactor operations generally limit the value of the creek and the adjacent swamp for wood stork foraging. Impacts to Four Mile Creek wood stork habitat resulting from the implementation of this alternative would be similar to those for the implementation of the same alternative for K-Reactor. Although the stream would be more attractive to fish and other vertebrates, the implementation of this alternative would not significantly improve the availability of wood stork foraging habitat because of high flows and water depth.

BC-3 Formal consultations were held between DOE and the FWS to comply with the Endangered Species Act of 1973. Based on these consultations, the FWS issued a biological opinion that the preferred alternative cooling systems should have no effect on endangered and threatened species (Parker, 1986; Henry, 1986).

Radiological Releases

The radiological releases associated with the discharge of cooling water from C-Reactor are those resulting from either the remobilization of radionuclides contained in the Four Mile Creek streambed and floodplains, or those resulting from small process water leaks into the cooling water.

BC-22 As in the K-Reactor evaluation, the operation of the once-through cooling tower at C-Reactor would not result in any significant changes in the remobilization of radionuclides contained in the streambeds and floodplains, because the flow rate of cooling water discharged to the creek would remain essentially unchanged. The operation of the cooling tower would, however, decrease the amount of tritium discharged to the stream and, correspondingly, would increase the amount of tritium released to the atmosphere.

Appendix G contains details of the dose assessment methodology and parameters; it also contains tables that list specific organ doses by pathway and age group.

Atmospheric Releases

The amount of tritium released to the atmosphere is expected to increase by 50 curies per year (about 0.012 percent of total SRP releases of tritium to the atmosphere) as a result of the cooling water evaporation. This release would increase the atmospheric dose commitments of the regional population and the maximally exposed individual. Changes in dose commitments resulting from the increased release of atmospheric tritium are summarized below.

BC-22

Maximum Individual Dose - The hypothetical individual who would receive the highest effective whole-body dose from atmospheric releases associated with this cooling alternative is assumed to reside continuously at the SRP boundary about 9.3 kilometers southwest of C-Reactor. This location has the minimum atmospheric dilution, based on distance to the Plant boundary and meteorological dispersion characteristics. This individual is assumed to receive the doses by inhalation and by the ingestion of meat, vegetation, and cow's milk.

The annual increases in soft-tissue and effective whole-body doses to the maximally exposed individual due to the atmospheric release of tritium are summarized in Table 4-16.

Table 4-16. Increase in Annual Doses to Maximally Exposed Individual Resulting from Atmospheric Releases of Tritium from C-Reactor Once-Through Cooling Tower

Age group	Incremental dose increase (mrem/yr)	
	Effective whole body	All soft tissue ^a
Adult	1.08×10^{-4}	1.27×10^{-4}
Teen	1.17×10^{-4}	1.37×10^{-4}
Child	8.09×10^{-5}	9.51×10^{-5}
Infant	2.40×10^{-5}	2.82×10^{-5}

a. Tritium imparts an equal dose to all soft tissues (i.e., all organs except bone) that is 18 percent higher than the effective whole-body dose.

Population Dose - Collective doses resulting from atmospheric releases associated with this cooling alternative have been calculated for the population within 80 kilometers of the Plant. The annual collective dose to this population would increase by 4.97×10^{-3} person-rem as a result of the increase in tritium released to the atmosphere.

Liquid Releases

The operation of the once-through cooling tower would reduce the amount of tritium released to Four Mile Creek. The release of tritium would be decreased by 50 curies per year (about 0.12 percent of total releases of tritium to streams) as a result of evaporation experienced during cooling. Doses associated with the change in liquid releases are discussed below for both the population and the maximally exposed individual.

Maximum Individual Dose - The annual decrease in soft-tissue and effective whole-body doses received by the maximally exposed individual (as described in Section 4.1.1.2) due to a decrease in the liquid release of tritium from C-Reactor would be the same as that for K-Reactor, which is summarized in Table 4-3.

Population Dose - Decreases in the collective dose to the population within 80 kilometers of the SRP and to the Beaufort-Jasper and Port Wentworth population groups due to a decrease in the liquid release of tritium from C-Reactor would be the same as those for K-Reactor, which are listed in Table 4-4.

Overall Changes in Offsite Doses

Table 4-17 summarizes changes in the effective whole-body dose received by the maximally exposed individual resulting from the operation of this cooling alternative. Changes in the collective dose resulting from the operation of a cooling tower at C-Reactor would be the same as those for K-Reactor, which are listed in Table 4-6.

Table 4-17. Changes in Effective Whole-Body Dose Received by Maximally Exposed Individual Resulting from Operation of C-Reactor Once-Through Cooling Tower (Millirem per Year)^a

Source of exposure	Adult	Teen	Child	Infant
Atmospheric tritium releases	1.08×10^{-4}	1.17×10^{-4}	8.09×10^{-5}	2.40×10^{-5}
Liquid tritium releases	$-2.19 \times 10^{-4}{}^{(b)}$	-1.54×10^{-4}	-1.50×10^{-4}	-9.52×10^{-5}
Net dose change	-1.11×10^{-4}	-3.70×10^{-5}	-6.91×10^{-5}	-7.12×10^{-5}

a. Tritium imparts a dose to soft tissues (i.e., all organs except bone) that is about 18 percent higher than the effective whole-body dose.

b. Negative sign denotes a decrease in dose.

TC | This cooling alternative would reduce the annual dose to the effective whole body of the maximally exposed adult and to Port Wentworth and Beaufort-Jasper water users by 1.11×10^{-4} millirem, 2.13×10^{-2} person-rem, and

1.13×10^{-2} person-rem, respectively, and would increase the collective effective whole-body dose to the 80-kilometer population by 4.95×10^{-3} person-rem. These dose changes are very small in comparison to the normal year-to-year variations in natural background radiation.

Present tritium releases to the Savannah River from Four Mile Creek result in an effective whole-body dose of 5.92×10^{-2} millirem per year to the maximally exposed adult. This alternative would reduce the liquid tritium dose by 2.19×10^{-4} millirem per year and increase the atmospheric dose by 1.08×10^{-4} millirem per year, resulting in an overall reduction of 1.11×10^{-4} millirem per year.

Health Effects

Using the risk estimators referred to in Section 4.1.1.2 and the organ doses presented in Appendix G, the population within 80 kilometers of the SRP could experience an annual increase of 5.82×10^{-7} excess cancer fatality and 1.50×10^{-6} additional genetic disorder from the operation of this alternative cooling water system. The populations at Beaufort-Jasper and Port Wentworth downstream from the Plant could experience decreases of 3.84×10^{-6} fatal cancer and 9.87×10^{-6} genetic disorder per year. Changes in annual health effects related to the operation of a cooling tower at C-Reactor would be the same as those for K-Reactor, which are listed in Table 4-7.

4.2.2 RECIRCULATING COOLING TOWERS

4.2.2.1 Construction Impacts

Socioeconomics

Construction of the recirculating cooling towers for C-Reactor would be accomplished in approximately 42 months following a 9-month design stage. Construction could involve a combined construction workforce for the cooling towers in K- and C-Areas. Section 4.1.2.1 describes the numbers and general types of workers required for construction of recirculating cooling towers for both K- and C-Reactors. This alternative would not impact local communities or services.

Historic and Archaeological Resources

The construction of recirculating cooling towers would disturb only one site (38BR548) in the Four Mile Creek area. Site 38BR548 is a small prehistoric lithic and ceramic scatter located on a terrace edge adjacent to the bank of the northern branch of Four Mile Creek. No impact mitigation has been recommended for this site, because the potential yield of additional research information is negligible (see Appendix E for more details).

Water Quality

The construction impacts of recirculating cooling towers on the water quality in Four Mile Creek would be the same as those described for a recirculating cooling tower for K-Reactor (Section 4.1.2.1). The principal impact would be some temporary localized increases in the suspended solids in the streams due

to runoff and erosion from construction activities. The application of standard erosion control practices would minimize these temporary effects.

Ecology

BB-3 | The construction of recirculating cooling towers would result in the
BC-9 | disturbance of approximately 60 acres of the habitat. This would include 21
acres for both cooling towers, 38 acres for the pipeline right-of-way, and the
remainder for the relocation of various facilities and for construction of
service roads and parking areas. No adverse effects are expected on
vegetation outside the immediate construction areas. Impacts on fish and
wildlife from the construction of recirculating cooling towers would be
similar to those associated with the construction of a once-through cooling
tower.

Radiological Releases

During the construction of recirculating cooling towers for C-Reactor, there would be no changes in the atmospheric and liquid releases of radionuclides. Reactor operation and the flow rate in Four Mile Creek would remain the same. There would be no changes in reactor releases or remobilization of radionuclides from the stream bed and, consequently, radiation doses to the offsite population would not change.

BC-9 | The only change would be in doses delivered to onsite construction personnel,
BC-22 | as discussed in Section 4.2.1.1. This dose, estimated to be approximately 20
millirem per year, is below the standards established by DOE for uncontrolled
areas of 25 millirem per year from airborne releases and 100 millirem per year
from all pathways.

Other Construction Impacts

Other construction impacts would be similar to those described for a once-through cooling-tower system for K-Reactor (i.e., air quality, noise, solid waste, and outside construction personnel exposure to radioactive releases). All applicable atmospheric emission standards would be met during construction, solid waste generated from construction would be disposed of in an approved manner, and fueling and maintenance of construction equipment would be performed under controlled conditions to minimize spills.

4.2.2.2 Operational Impacts

Socioeconomics

Six additional mechanics would be required to support the operation of recirculating cooling towers at C-Reactor; the employment of these workers would not cause any socioeconomic impacts in the study area.

Historic and Archeological Resources

Operational activities related to recirculating cooling towers for C-Reactor would not impact any historic and archaeological resources. During the operation of the towers, cooling water effluent flows in Four Mile Creek would

be reduced significantly. An archaeological and historic resources survey in the Four Mile Creek watershed area located no significant sites requiring impact mitigation.

Water Quality and Hydrology

The effects of the operation of recirculating cooling towers on water quality would be similar to those described for K-Reactor (see Section 4.1.2.2). The operation of recirculating cooling towers would lower discharge temperatures such that the State of South Carolina's Class B water classification standard for maximum instream temperature (32.2°C) would be met throughout the year. However, the discharge from the cooling tower would raise the stream temperature in Four Mile Creek more than the 2.8°C maximum above ambient specified in the water classification standards. Accordingly, a Section 316(a) Demonstration study would be performed to demonstrate if a balanced biological community would be maintained. The flow of Four Mile Creek would be reduced from 11.3 to 1.7 cubic meters per second, similar to that described for Pen Branch with the operation of recirculating towers for K-Reactor (see Section 4.1.2.2).

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Air Quality

Air quality impacts from the operation of recirculating cooling towers at C-Reactor would be identical to those addressed in Section 4.1.2.2 for the K-Reactor recirculating cooling-tower.

BC-9

Noise

The operation of the C-Reactor recirculating cooling towers would cause increases in noise levels. The impacts would be similar to those described in Section 4.1.2.2.

Ecology

Vegetation and Wetlands

The vegetation near the recirculating cooling towers would not be affected adversely by drift from the towers. Operation of the recirculating cooling towers would result in an estimated total solids deposition of about 2.2 kilograms per acre per year within 2 kilometers and 22.7 kilograms per acre per year within 0.5 kilometer of the cooling towers. Because these rates would be much less than the critical values, no significant impacts on vegetation should occur with this alternative.

BB-3
BC-9

The primary positive impact on vegetation would be a reduction in the loss of wetland habitat due to reductions in discharge temperature and flow. The operation of recirculating cooling towers would reduce the rate of growth of the delta and allow the reestablishment of vegetation through the process of natural succession for an estimated 1000 acres of wetland habitat that are presently subject to thermal discharges and flooding.

To assist in ongoing consultations with FWS, a HEP analysis (Mackey et al., 1987) was conducted; it identified the value of habitat to be gained or lost

BC-3

BC-3 | with the recirculating cooling-tower alternative (see Section 4.6 and Appendix C for more details on HEP analysis).

Aquatic Habitat and Biota

The environmental consequences resulting from the operation of a recirculating cooling-tower system on aquatic habitat and biota in Castor and Four Mile Creeks would be similar to those described for Indian Grave Branch and Pen Branch from K-Reactor discharges.

Entrainment and Impingement

BB-3 | The estimated numbers of ichthyoplankton entrained and fish impinged from
BD-9 | operation of the recirculating cooling-tower system for C-Reactor would be the same as those described for K-Reactor because both reactors draw cooling water from the same sources (1G and 3G canals) and would require the same circulating water volume.

Threatened and Endangered Species

BB-3 | Implementation of the recirculating alternative would result in a reduction of the effluent discharge in Four Mile Creek from about 11.3 to about 1.7 cubic meters per second. This would allow the stream channel to revert approximately to its original width, and would allow fish and invertebrates to inhabit the stream channel. Habitat quality for the American alligator would be markedly improved over present conditions; inundation of nests, eggs, and hibernation sites from high water levels would be improbable.

TC | Formal consultations were held between DOE and the FWS to comply with the Endangered Species Act of 1973. Based on these consultations, the FWS issued a biological opinion that the preferred alternative cooling systems should have no effect on threatened and endangered species (Parker, 1986; Henry, 1986).

Radiological Releases

Appendix G contains details of the dose assessment methodology and parameters; it also contains tables that list specific organ doses by pathway and age-group. The operation of recirculating cooling towers would reduce the flow rate of cooling water in Four Mile Creek and, therefore, decrease the amount of radionuclides being remobilized from the stream bed and transported to the Savannah River. The only radionuclide contained in the Four Mile Creek bed in significant amounts is cesium-137 (Appendix D). The reduced flow would result in a decrease of about 0.21 curie of cesium-137 released per year to the Savannah River.

BC-22 | Maximum Individual Dose - Table 4-18 lists the changes in effective-whole-body and most-affected-organ (gonads) doses to the maximally exposed individual resulting from the decrease in cesium-137 released to the Savannah River.

Population Dose - Table 4-19 lists the decreases in the collective doses delivered to the affected population groups.

Table 4-18. Decrease in Doses to Maximally Exposed Individual Resulting from Cesium Redistribution Associated with C-Reactor Recirculating Cooling Towers

Age group	Incremental dose reduction (mrem/yr)	
	Effective whole body	Gonads ^a
Adult	1.20×10^{-1}	1.20×10^{-1}
Teen	9.21×10^{-2}	9.23×10^{-2}
Child	4.00×10^{-2}	4.01×10^{-2}
Infant	3.86×10^{-4}	3.86×10^{-4}

- a. Dose to gonads is directly comparable to soft tissue doses resulting from tritium, because tritium imparts an equal dose to all soft tissues (i.e., all organs except bone).

BC-22

Table 4-19. Decrease in Collective Effective Whole-Body Dose Resulting from Cesium Redistribution Associated with C-Reactor Recirculating Cooling Towers

Population group	Incremental collective dose reduction (person-rem/yr)
80-km population	3.35×10^{-1}
Beaufort-Jasper	1.83×10^{-2}
Port Wentworth	6.67×10^{-2}
Total	4.20×10^{-1}

Tritium Releases

The following sections discuss changes in the doses to the maximally exposed individual at the SRP boundary and to offsite population groups (based on year 2000 projections) that are attributable to changes in atmospheric and liquid releases to Four Mile Creek of tritium resulting from operation of recirculating cooling towers.

Atmospheric Releases - The amount of tritium released annually to the atmosphere is expected to increase by 425 curies (about 0.1 percent of total SRP releases of tritium to the atmosphere) as a result of evaporation experienced during cooling. This would increase the atmospheric dose commitments of the regional population and the maximally exposed individual.

Changes in dose commitments resulting from the increased release of atmospheric tritium are summarized below.

Maximum Individual Dose - The hypothetical individual who would receive the highest effective whole-body dose from atmospheric releases associated with this cooling alternative is the same as that described in Section 4.2.1.2.

Table 4-20 summarizes the annual increases in soft-tissue and effective whole-body doses received by the maximally exposed individual due to the atmospheric release of tritium.

Table 4-20. Increase in Annual Doses to Maximally Exposed Individual Resulting from Atmospheric Releases of Tritium from C-Reactor Recirculating Cooling Towers

Age group	Incremental dose increase (mrem/yr)	
	Effective whole body	All soft tissues ^a
Adult	9.15×10^{-4}	1.08×10^{-3}
Teen	9.91×10^{-4}	1.17×10^{-3}
Child	6.87×10^{-4}	8.09×10^{-4}
Infant	2.03×10^{-4}	2.40×10^{-4}

a. Tritium imparts an equal dose to all soft tissues (i.e., all organs except bone) that is 18 percent higher than the effective whole-body dose.

Population Dose - Collective effective whole-body doses to the population within 80 kilometers of the SRP associated with this cooling alternative would increase by 4.22×10^{-2} person-rem per year as a result of the increase in tritium released to the atmosphere.

Liquid Releases - The operation of this cooling alternative would reduce the amount of tritium released to the stream by 425 curies per year (about 1 percent of the total SRP releases of tritium to streams) as a result of evaporation of cooling water. Doses associated with the change in liquid releases are discussed below for both the population and the maximally exposed individual.

Maximum Individual Dose - The annual decrease in soft-tissue and effective whole-body doses received by the maximally exposed individual due to a decrease in the liquid release of tritium from C-Reactor is the same as that for K-Reactor, which is summarized in Table 4-11.

Population Dose - Decreases in the effective whole-body dose to the population within 80 kilometers of the SRP and to the Beaufort-Jasper and Port Wentworth

TE

population groups due to a decrease in the liquid release of tritium from C-Reactor would be the same as those for K-Reactor, which are listed in Table 4-12.

Overall Changes in Offsite Doses

Table 4-21 summarizes changes in the effective whole-body and most-affected-organ doses received by the maximally exposed individual resulting from the operation of this cooling alternative. Table 4-22 lists changes in the effective whole-body population dose.

Table 4-21. Changes in Effective Whole-Body and Gonadal Doses Received by Maximally Exposed Individual Resulting from Operation of C-Reactor Recirculating Cooling Towers (millirem per year)

Source of exposure	Adult	Teen	Child	Infant
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EFFECTIVE WHOLE-BODY DOSE INCREMENT

Atmospheric tritium releases ^a	9.15×10^{-4}	9.91×10^{-4}	6.87×10^{-4}	2.03×10^{-4}
Liquid tritium releases ^a	$-1.85 \times 10^{-3(b)}$	-1.31×10^{-3}	-1.27×10^{-3}	-8.06×10^{-4}
Cesium transport	-1.20×10^{-1}	-9.21×10^{-2}	-4.00×10^{-2}	-3.86×10^{-4}
Net dose change	-1.21×10^{-1}	-9.24×10^{-2}	-4.06×10^{-2}	-9.89×10^{-4}

BC-22

GONADAL DOSE INCREMENT^c

Atmospheric tritium releases ^a	1.08×10^{-3}	1.17×10^{-3}	8.09×10^{-4}	2.40×10^{-4}
Liquid tritium releases ^a	-2.18×10^{-3}	-1.53×10^{-3}	-1.50×10^{-3}	-9.48×10^{-4}
Cesium transport	-1.20×10^{-1}	-9.23×10^{-2}	-4.01×10^{-2}	-3.86×10^{-4}
Net dose change	-1.21×10^{-1}	-9.27×10^{-2}	-4.08×10^{-2}	-1.09×10^{-3}

BC-22

- Tritium imparts a dose to soft tissues (i.e., all organs except bone) that is about 18 percent higher than the effective whole-body dose.
- Negative sign preceding number denotes a decrease in dose.
- Gonadal dose is directly comparable to soft tissue doses resulting from tritium since tritium imparts an equal dose to all soft tissues (i.e., all organs except bone).

The recirculating cooling-tower alternative would reduce the annual effective whole-body dose to the maximally exposed adult by 1.21×10^{-1} millirem, and the collective effective whole-body dose to the 80-kilometer population and the Port Wentworth and Beaufort-Jasper water users by 2.93×10^{-1} , 2.49×10^{-1} , and 1.14×10^{-1} person-rem per year, respectively. These changes

BC-22

Table 4-22. Changes in Collective Effective Whole-Body Dose Resulting from Operation of C-Reactor Recirculating Cooling Towers (Person-rem per Year)

Source of exposure	80-kilometer population	Beaufort Jasper	Port Wentworth	Total
EFFECTIVE WHOLE-BODY DOSE INCREMENT				
Atmospheric tritium releases	4.22×10^{-2}	-	-	4.22×10^{-2}
Liquid tritium releases	$-2.09 \times 10^{-4} \text{ (a)}$	-9.58×10^{-2}	-1.82×10^{-1}	-2.78×10^{-1}
Cesium transport	-3.35×10^{-1}	-1.83×10^{-2}	-6.67×10^{-2}	-4.20×10^{-1}
Net dose change	-2.93×10^{-1}	-1.14×10^{-1}	-2.49×10^{-1}	-6.56×10^{-1}

a. Negative sign preceding number denotes decrease in dose.

BC-22 are very small compared with normal year-to-year variation in natural background radiation.

BC-22 Present SRP operations result in an effective whole-body dose of 5.92×10^{-2} millirem per year to the maximally exposed adult from tritium releases to the Savannah River from Four Mile Creek. This alternative would reduce the liquid tritium dose by 1.85×10^{-3} millirem per year and increase the atmospheric tritium dose by 9.15×10^{-4} millirem per year, resulting in an overall reduction of 9.35×10^{-4} millirem per year. Similarly, the effective whole-body dose to the maximally exposed adult from cesium releases is 1.37×10^{-1} millirem per year. This alternative would reduce this dose by 1.20×10^{-1} millirem per year.

Health Effects

BC-22 Using the organ doses and the risk estimators discussed above and presented in Appendix G, the population within 80 kilometers of the Savannah River Plant could experience a decrease of 2.31×10^{-5} cancer fatality and 7.37×10^{-5} genetic disorder per year from the operation of this system. The populations at Beaufort-Jasper and Port Wentworth downstream from the SRP could experience decreases of 3.98×10^{-5} fatal cancer and 1.06×10^{-4} genetic disorder per year. Table 4-23 summarizes this information.

4.2.3 NO ACTION - EXISTING SYSTEM

The no-action alternative for C-Reactor would maintain the existing once-through cooling water system that withdraws water from the Savannah River (via the 1G and 3G intakes) and discharges it into Four Mile Creek. Chapter 3

Table 4-23. Changes in Annual Health Effects

Population group	Genetic disorders	Fatal cancers
80-kilometer radius	-7.37×10^{-5}	-2.31×10^{-5}
Beaufort-Jasper	-3.37×10^{-5}	-1.28×10^{-5}
Port Wentworth	-7.22×10^{-5}	-2.70×10^{-5}
Total	-1.80×10^{-4}	-6.29×10^{-5}

TC

and Appendix C describe the environmental baseline conditions associated with this system. This section summarizes the major environmental impacts of the existing system.

4.2.3.1 Water Quality and Hydrology

The annual average flow in Four Mile Creek downstream of the C-Reactor cooling water discharge point would continue to be about 11.3 cubic meters per second higher than the natural stream flow of 0.6 cubic meter per second. The pattern of erosion upstream and deposition downstream would continue, and the delta at the stream mouth would continue to grow.

Water temperatures in the creek downstream of the point of discharge from C-Reactor would have an annual average of about 38.5°C. Above the discharge, the mean temperature would be about 17.8°C. The highest temperatures would occur during extreme summer conditions, when the effluent would reach about 75°C, falling to about 44°C at the swamp. Ambient stream temperatures would be about 31°C at these times. In the winter months, temperatures in the creek and swamp would range from 72° to 35°C, while ambient stream temperatures would be about 11°C. These conditions would be present only when the reactor was operating. The continuation of the existing cooling water discharge from C-Reactor would not comply with the State of South Carolina's Class B water classification standards.

TC

Lowered dissolved oxygen concentrations would continue to exist as a result of elevated water temperatures in the creek. Mean annual oxygen levels downstream of the discharge would be about 6.6 milligrams per liter. Concentrations frequently would fall below minimum State Class B standards (5 milligrams per liter) in portions of the creek primarily during reactor operations in the summer.

Nutrient concentrations in Four Mile Creek generally would be higher than those that would occur naturally in these waterways because of the higher concentrations of these substances in the Savannah River water used for cooling. Nitrate levels are also higher (e.g., above the discharge point) due to effluents from the upstream process areas. The thermal reaches of Four Mile Creek would display mean concentrations of total phosphorus, orthophosphates, nitrite, and Kjeldahl (total) nitrogen slightly lower than

those of the Savannah River (but still higher than ambient creek levels) (Du Pont, 1985b). Ammonia concentrations in Four Mile Creek would also be slightly lower than in the river, but would still be about twice as great as those in nonthermal portions of the creek.

4.2.3.2 Ecology and Wetlands

TC

Aquatic and adjacent terrestrial environments of Four Mile Creek would continue to be influenced by the thermal releases from C-Reactor. The flora along the creek would continue to be sparse, reflecting the influence of high flow and elevated water temperatures. In backwaters and shallow areas, thick mats of blue-green algae would continue to cover the bottom. Tag alder and wax myrtle would dominate the riparian vegetation. Further downstream toward the swamp, where the stream is braided over a marsh-like area and a few standing dead bald cypress remain, the deeper channels would be relatively free of vegetation, with thick growths of sedges along the banks. Mats of blue-green algae would also cover the shallower areas in these reaches. About 1147 acres of wetlands would continue to be affected in the Four Mile Creek floodplain and swamp; the loss of swamp and canopy would continue to proceed at the rate of approximately 28 acres per year (Du Pont, 1987).

Most aquatic invertebrate species would continue to be absent from the creek due both to the high water temperatures during operations and to the scouring effect of the effluent flow. In the downstream delta and swamp areas, macroinvertebrates would be present, but in lower species richness than those in comparable ambient areas. Fish would not inhabit the thermal reaches of Four Mile Creek except when the reactor is not operating or during periods when the Savannah River floods into the SRP swamp.

The fish fauna upstream of the discharge point would continue to be depauperate (i.e., poor or reduced) in both numbers and diversity. Fish would be expected to be in low abundance in the mouth of the creek except during the winter, when they are attracted to the warm water plume, making them vulnerable to cold shock when the reactor is shut down. Fish in the Savannah River would not be affected by the discharge plume from Four Mile Creek; a year-round zone of passage around the plume would be present in the river.

TC

High Savannah River flows would transport ichthyoplankton into thermally impacted portions of the swamp from adjacent unimpacted areas. In addition, some fish use thermally impacted areas for spawning during high river flows, because flow patterns for the heated water are altered dramatically during those periods (Du Pont, 1985b, 1987).

Wildlife and habitat for wildlife in the Four Mile Creek delta system would be similar to those found in the Pen Branch area.

4.2.3.3 Entrainment and Impingement

BB-3
BD-5

The estimated numbers of ichthyoplankton entrained and fish impinged as a result of use of the no-action alternative for C-Reactor would be the same as those described for this alternative with K-Reactor (Section 4.1.3.3) because the two reactors draw cooling water from the same sources (1G and 3G canals) and would require the same circulating water volume.

4.2.3.4 Threatened and Endangered Species

Temperatures in the thermal region of Four Mile Creek during reactor operations would continue to exceed the critical thermal maximum for the American alligator (Du Pont, 1985b). Four Mile Creek and the swamp would continue to be unfavorable to wood stork foraging due to the low fish densities, high water temperatures, and increased water depths. Shortnose sturgeon larvae and adults have never been collected from Four Mile Creek and neither would be expected if the no-action alternative were implemented.

TC

4.3 ALTERNATIVES FOR D-AREA COAL-FIRED POWERHOUSE

The alternatives for the D-Area coal-fired powerhouse are increased flow with mixing, direct discharge to the Savannah River, and no action. The following sections describe the environmental consequences of these alternatives.

4.3.1 INCREASED FLOW WITH MIXING

4.3.1.1 Construction Impacts

This alternative could be implemented immediately after compliance with applicable environmental approvals (Chapter 5). No construction activities would be required to implement this alternative; hence, there are no environmental impacts due to construction.

4.3.1.2 Operational Impacts

Socioeconomics

This alternative would produce no socioeconomic impacts because it would not require any additional workers for operation.

Historic and Archaeological Resources

Operational activities related to this alternative would produce slight periodic increases in water flow in Beaver Dam Creek; however, no archaeological and historic resources would be impacted (Appendix E).

Water Quality and Hydrology

Water quality monitoring studies conducted in Beaver Dam Creek from 1973 to 1982 have shown that, with the exception of temperature, all South Carolina Class B water classification standards have been met (Du Pont, 1985b). This cooling water alternative would discharge through NPDES-permitted outfall D-001, which has daily maximum discharge limitations of 40 milligrams per liter of total suspended solids and 15 milligrams per liter of oil and grease, and a temperature limitation of 32.2°C.

The implementation of this alternative would reduce the effluent water temperatures in downstream areas, including the swamp (see Section 2.2.3.1) and would meet all NPDES permit requirements at outfall D-001, with the exception of a maximum rise in ambient stream temperatures of 2.8°C during

the winter. A Section 316(a) Demonstration study would be performed to determine whether a balanced biological community would be maintained. Water temperatures in Beaver Dam Creek during the spring and summer would more closely approximate the normal temperature regime of unaffected streams in the area after the implementation of increased pumping to meet permitted requirements.

Increased flow with mixing would produce temporary increases in suspended solids in the creek channel above the swamp due to the erosion of the streambed and banks or the resuspension of previously settled material caused by the intermittent increased flow. The total load of suspended material in Beaver Dam Creek, however, would be no higher than that experienced in previous years. This total loading would return to near previous levels after the stream channel has reached equilibrium, and the resultant stream water temperature would reduce heat-related loss of streambank vegetation.

Increased flow with mixing could cause the flow in Beaver Dam Creek at the SRP Health Protection Department monitoring station to increase to 4.0 cubic meters per second (five pumps) during periods of peak summer temperatures. This would result in changes in stream morphology as a result of erosion and sedimentation, as well as the increased volume of water that would be carried intermittently by the creek. Some fluctuations now occur in the flows in the stream as a result of the powerhouse loads and/or maintenance outages. Generally, these changes are small and occur infrequently.

To assess the potential impact of increased flows, DOE conducted a pump test in Beaver Dam Creek during a 7-day period in June 1985. Under normal conditions, three pumps at the 5G pumphouse provide cooling water to D-Area. During the test, one additional pump and then two additional pumps were brought into service to study the impacts on water levels in the swamp. Water levels were monitored at eight locations along the creek and in the swamp. The results of the test indicated that water levels in the upper and lower channels of the creek rose and then declined to some extent. With four pumps operating, the water level increased by about 10 centimeters within 8 hours and then declined by 2 centimeters during the next 2 days. Following the activation of the fifth pump, the total rise in the water level was initially 17 centimeters over the pretest conditions; however, the water surface fell about 5 centimeters during continued pumping the next 5 days. Water levels in the swamp increased by 14 centimeters during the test and were still increasing at a rate of 0.5 centimeter per day when the pump test ended. With the increased flow alternative, pump tests indicate that the water levels in Beaver Dam Creek and swamp should increase between 12 and 19 centimeters over present levels during those times when flow will be augmented (Specht, 1985).

Air Quality and Noise

Increased flow with mixing would produce a small increase in average noise levels in the immediate area of the pumps when increased pumping is required during the summer. At the nearest offsite area, the increased levels of noise would be negligible. In the area of the pumps and in other areas where workers might be exposed to equipment noise, workers would wear protective equipment in accordance with applicable standards and regulations. Increased flow with mixing would cause no increase in local atmospheric emissions of

pollutants due to the increased pumping, but would require additional electricity and attendant emissions. Emissions currently meet all applicable air quality standards.

Ecology

Habitat and Biota

Balanced communities in all biotic categories presently exist in all natural portions of the Beaver Dam Creek ecosystem and should remain after the implementation of this alternative. Predicted maximum water temperatures would not exceed 32°C and, therefore, would comply with the maximum of 32.2°C required for Class B waters of South Carolina. However, the other temperature criterion for Class B waters (maximum ΔT of 2.8°C above ambient) would be exceeded by as much as an average monthly value of 10°C in the immediate discharge area and by as much as 7°C at the creek mouth (see Appendix B, Tables B-4 and B-5). Accordingly, a Section 316(a) Demonstration would be conducted for NPDES compliance after this alternative system becomes operational.

BB-3

Increased flow during the summer should increase aquatic habitat and the abundance and diversity of aquatic biota. However, terrestrial wildlife habitat would be reduced and associated wildlife would be displaced temporarily during periods of increased pumping. An estimated 4 acres each of uplands and wetlands would be inundated temporarily because of intermittent flooding from increased flow.

The increase in pumping probably would cause a temporary increase in the erosion of the stream channel. The adverse effects of siltation on aquatic organisms and their habitats are well documented (Ellis, 1936; Hynes, 1970; Marzolf, 1980; Adams and Beschta, 1980). These temporary increases in siltation could result in reduced primary productivity and reduced populations of some benthic invertebrates, and could reduce fish spawning and feeding habitat downstream if increased pumping were to occur during the spawning season. However, increased pumping probably would not be required during the peak spawning period of fish in Beaver Dam Creek. The expected erosion and the resulting siltation would equilibrate rapidly under an increased flow regime. Most adverse impacts from increased siltation in streams are temporary, and biota quickly recolonize after the disturbance has ceased (Barton, 1977; Boschung and O'Neil, 1981).

To compare and assess environmental impacts to the Beaver Dam Creek watershed before and after the implementation of this alternative, the stream system has been divided into two reaches on the basis of the presence of two distinct stream gradients: Reach 1 extends from the D-Area powerhouse cooling water discharge outfall (NPDES Outfall D-001) to the mouth of the Beaver Dam Creek delta; Reach 2 extends from the delta to the Savannah River.

BB-3

Beaver Dam Creek is a low potential impact area for phytoplankton, because phytoplankton do not contribute significantly to the food chain base. The food base throughout the creek consists of detrital material rather than phytoplankton, as is typical in lotic systems. Primary producers in the Beaver Dam Creek system consist mainly of periphyton and macrophytes (Du Pont, 1987).

Following implementation of this alternative, a diverse zooplankton community should remain in Beaver Dam Creek; this community should not be affected adversely by D-Area powerhouse operation. Rather, increased flow with mixing should enhance the zooplankton communities in the immediate discharge area by eliminating potential exposures to lethal temperatures (greater than 32°C). The maximum predicted summer temperatures in Reaches 1 and 2 would be 32°C and 31°C, respectively (see Appendix B, Tables B-4 and B-5). These temperatures are within the range tolerated by most, if not all, indigenous species; indeed, ambient summer water temperatures in many southeastern streams equal or exceed these values.

The zooplankton community should provide food for balanced indigenous macroinvertebrate and fish communities. The heated discharge should not alter the standing crop, community structure, or seasonal periodicity of zooplankton in the farfield study area from those values typical of the receiving water-body segment prior to SRP operation. Furthermore, the thermal plume resulting from powerhouse operation should not constitute a lethal barrier to the free movement (drift) of zooplankton.

BB-3 The increased flows and reduced temperatures associated with this alternative should not cause significant deterioration of the habitat-formers community in the Beaver Dam Creek system. Because increased temperatures affect species composition by reducing diversity, altering species dominance, or even eliminating some species, the reduced temperatures should improve the habitat-formers community. Scouring due to the increased flow would affect primarily Reach 1 of Beaver Dam Creek. At present, macrophytes are not present in this reach of the stream due to water velocity and turbidity (Du Pont, 1987). The habitat-formers community in the delta and swamp areas should not be affected significantly by increased flows because fluctuations of flow and increases in current velocity through these areas would not be as rapid or severe as those in Reach 1.

During the summer months, increased pumping would reduce stream water temperatures in comparison to existing conditions, and would provide a thermal regime that should support a diverse macroinvertebrate community. The maximum predicted summer temperatures in the two reaches of the stream would not exceed 32°C and 31°C, respectively. These temperatures are within the range tolerated by most, if not all, indigenous species of macroinvertebrates.

Implementation of this alternative should not result in major changes to the structure and function of the existing macroinvertebrate community, although some minor shifts in the relative abundance of some taxa probably would occur. Increases in water velocity during increased pumping would favor such taxa as Ephemeroptera and Trichoptera, many species of which prefer faster flowing water. Conversely, species that prefer slow flowing water (i.e., amphipods and water mites) could exhibit some decline in density and relative abundance during certain periods of operation.

The increased water velocity could result in temporary increases in the drift rate of some species of macroinvertebrates, such as those that would occur after a heavy rainfall. However, the macroinvertebrate community should be able to sustain the slightly higher rates of drift and would not be affected adversely. Increased rates of macroinvertebrate drift would provide additional food for higher trophic levels (i.e., fish).

Increases in water depth of 10 to 20 centimeters often occur naturally in Beaver Dam Creek during periods of heavy rainfall and should not affect the macroinvertebrate community adversely. The rise in water level would inundate the edges of the stream and, during periods of extended pumping, could result in some increases in the overall amount of aquatic habitat available for colonization. When increased pumping stopped, the water levels should recede gradually and not result in significant stranding of macroinvertebrates.

Although no data are available on insect emergence patterns in Beaver Dam Creek, early emergence probably occurs at present due to the elevated thermal regime of the creek. Increased pumping should not alter the present emergence patterns, because water temperatures in the winter would not be altered. The cooler water temperatures that would exist in Beaver Dam Creek during the summer months could result in the addition of a few species of macroinvertebrates that cannot tolerate the present summer temperatures. However, no major shifts in species composition, density, or standing crop of the macroinvertebrate community of Beaver Dam Creek should occur. The macroinvertebrate community should provide the food necessary for the maintenance of a balanced indigenous fish community.

The thermal plume resulting from the D-Area cooling water discharge would not interfere with the drift or upstream movement of macroinvertebrates, if such movement were possible. However, because Beaver Dam is an intermittent stream above the outfall, little, if any, drift or upstream movement is possible. Increased pumping should not have any impact on the community structure, standing crop, or seasonal periodicity of macroinvertebrates in the farfield study area. The temperatures of the thermal plume would not constitute a barrier to either the drift or the upstream movement of macroinvertebrates.

BB-3

The fish community of Beaver Dam Creek should not suffer appreciable harm from the operation of the D-Area powerhouse following increased flow with mixing. There should be no direct or indirect mortality from excess heat or cold shock. The absolute maximum monthly predicted water temperature at the powerhouse discharge compliance point would be 32°C and the maximum predicted average monthly value would be 29°C (see Appendix B, Tables B-4 and B-5). In contrast, the upper incipient lethal temperatures for representative and important species (largemouth bass, bluegill, and catfish) are in the mid- to upper 30s°C. Because the maximum average monthly temperature increase above ambient (ΔT) in the vicinity of the discharge following implementation of this alternative would be no more than 10°C, cessation of heated discharges during the winter months should not result in cold shock to fish. Reproductive success and growth of all indigenous species of fish should be similar to present conditions with this alternative; growth should be enhanced because the slight warming from the powerhouse discharge results in optimal growth temperatures occurring for more of the year than with ambient conditions. Maximal absolute temperatures (32°C) and average monthly ΔT values (4°C-10°C) should not block fish migration. Thus, the entire Beaver Dam Creek system would be available for fish habitation; the free movement of fishes between the headwaters of Beaver Dam Creek and the Savannah River would not be inhibited by powerhouse operations at any time during the year.

BB-3

The increased-flow alternative should not cause significant changes to spawning activities in Beaver Dam Creek. Cooler summer temperatures caused by increased flow and mixing could enhance summer spawning. However, this could be offset by the increased variability of flow and temperature resulting from implementation of this alternative.

Entrainment and Impingement

The increase in cooling water flow through the 5G intake resulting from the implementation of this alternative would occur only during periods when ambient Savannah River water temperatures approach 32.2°C (May through September). Entrainment studies conducted at the 5G intake annually from 1983 to 1985 have produced estimates that an average of 1.2×10^6 fish larvae and an average of 0.8×10^6 fish eggs are entrained during the February-July spawning season as a result of cooling water withdrawal for the D-Area powerhouse (DOE, 1987a; Appendix C). Specht (1985), using entrainment data collected at the 5G intake during 1984, estimated that approximately 3 percent additional fish eggs and larvae would be entrained annually if increased pumping were required during the May-to-September time period (based on the 32.2°C temperature requirement). Application of this increased factor to the entire 1983-1985 entrainment data set yields a projection of an additional 3.6×10^4 fish larvae and 2.4×10^4 fish eggs entrained each year if the increased pumping alternative were implemented during the May-to-September time period. With this increase, entrainment at the 5G intake structure resulting from the operation of the D-Area powerhouse would average 1.2×10^6 fish larvae and 0.8×10^6 fish eggs per year. The principal species affected would be the clupeids, centrarchids, and cyprinids. The overall impact to fishery resources would be minimal.

BD-5

The rate at which fish are impinged on the intake screens at SRP pumphouses is related not only to the volume of water pumped but also to such factors as river water level, water temperature, and the density and species of fish in the intake canal (Du Pont, 1985b). Current rates of impingement at the 5G intake structure are based on studies conducted annually from 1983 to 1985, which determined that an average of 1717 fish are impinged each year as a result of cooling water withdrawal for the D-Area powerhouse (DOE, 1987). During this 3-year sampling period, approximately 93 percent of all fish collected were impinged during the March-to-May time period. Rates of increased impingement based on Specht (1985), using sampling data collected during 1984, and on estimates of the rate of increased pumping, the number of pumps operating, and the number of days that pumping would be required during the spring and summer to meet the 32.2°C temperature requirement led to projections that utilization of the increased-pumping alternative during 1984 would have resulted in an additional 14 fish being impinged at the 5G intake structure. Estimated annual impingement during 1984 was 213 fish (DOE, 1987); therefore, this amounts to a 6.6-percent increase. Application of this factor to the entire 1983-1985 impingement data set for the 5G intake yields a projected increase of 113 fish impinged per year when the increased pumping alternative is used. With this increase, impingement at the 5G intake structure resulting from the operation of the D-Area powerhouse would average 1831 fish per year. The principal species impacted would be the centrarchids and clupeids. The overall impact to fishery resources would be minimal.

Threatened and Endangered Species

American Alligator - Dense populations of alligators occur on Beaver Dam Creek and in the swamp associated with the creek (Du Pont, 1985b, 1987). These large populations probably occur because of the excellent breeding/nesting habitat associated with the backwaters along the creek and a reduction of alligator mortality. The mildly thermal effluent can provide refugia for alligators in the winter or, alternatively, enhance the growth rate of juveniles, which increases their survivability.

A minimum of 28 alligators representing all size classes (equivalent to age classes) longer than 1 meter inhabit this stream (based on aerial surveys from December 1983 to March 1984). Subsequent ground surveys in April and May 1984 resulted in the capture of 11 alligators representing age classes of 1-, 2-, and 3-year-olds. The backwater areas along the creek probably support a self-sustaining alligator population because all age classes of juveniles and adults have been observed (Du Pont, 1985b).

The primary impacts of this alternative on the alligator would be cooler effluents during the summer and intermittently increased water levels caused by the larger cooling water flows. Effluent temperatures under this alternative would be well below the alligator's critical thermal maximum during the summer; these temperatures are not expected to produce negative impacts on survivability. The heated effluent would continue to provide a thermal "refuge" for the alligator during the winter. This winter refuge would continue to enhance the growth rate and lower the mortality in juvenile age classes. Water level increases less than about 35 centimeters are not likely to impact alligator nesting sites in Beaver Dam swamp (personal communication, R. Siegel, Savannah River Ecology Laboratory). Thus, the increased flow from D-Area should not affect the American alligator adversely.

Bald Eagle - The first sighting of an active bald eagle nest on the SRP occurred on June 5, 1986. The nest is below Par Pond dam in the Lower Three Runs Creek drainage basin. Because of the nest location and due to the implementation of management practices in accordance with the guidelines of the 1984 bald eagle recovery plan, the FWS issued a finding of no effect to this endangered species in 1986 (Henry, 1986).

BB-3

Wood Stork - Based on 1983 data, the last wood stork observed feeding on the Savannah River Plant occurred on August 1, 1983. By August 15, the majority of the storks had dispersed from the Birdsville colony; by August 24, all had dispersed. Aerial and ground surveys for wood storks continued until September 27, but there were no additional observations of foraging on the Plant (Meyers, 1984).

During 1984, an average of 13 wood storks were observed during 89 surveys between May and mid-November (Coulter, 1986). The Steel Creek delta, Beaver Dam Creek, and the swamp between Pen Branch and Four Mile Creek were used by the wood stork to the greatest extent in 1984. However, on only 3 of the 12 occasions when wood storks were observed on Four Mile Creek were there more than two storks in each siting (Coulter, 1986). Beaver Dam Creek was important to wood storks in 1983 and 1984 but no individuals were observed in 1985. In 1986, a total of 15 wood storks was observed at the Beaver Dam Creek delta (Du Pont, 1987).

The primary impacts on the wood stork from the implementation of this alternative for D-Area would be intermittently increased water levels and decreased effluent temperatures during the summer. Effluent temperatures would be below 32.2°C during these months, thereby having minimal impact on foraging habitat.

BB-3 | Based on flow testing, the increased flow would raise water levels in the swamp by approximately 12 to 19 centimeters (Specht, 1985). Optimal average water depths for wood stork foraging is 25 centimeters. Depending on the initial water levels in foraging pools in the swamp, the 12- to 19-centimeter increase probably would reduce the availability of foraging sites in the Beaver Dam Creek delta area (Du Pont, 1987).

If increased pumping occurs when wood storks are actively foraging in the area and prey were optimally concentrated, the prey could be dispersed temporarily by the increased flow; however, because the water levels fall quickly in response to a decrease in pumping, this habitat would again be available to the wood stork. Because the wood stork is an opportunistic feeder, it would probably utilize this foraging source after it is reestablished. Flow fluctuations can also enhance foraging habitats by delaying or preventing such habitat from drying up, as noted by the U.S. Fish and Wildlife Service in its consultation for Steel Creek (FWS, 1984a). In addition, increased pumping would delay the reestablishment of a closed canopy, which could continue to provide foraging habitat for the wood stork.

Red-Cockaded Woodpecker - Nesting and foraging habitats for the red-cockaded woodpecker occur near Route 278 in the northeastern corner of the Plant and between Lower Three Runs Creek and Meyers Branch. D-Area operations would have no impact on these habitats.

Shortnose Sturgeon - Increased flow from this alternative would have no effect on the population status of shortnose sturgeon in the Savannah River. Suitable habitat exists above and below the Plant, based on the presence of spawning sturgeon and larvae.

Entrainment of shortnose sturgeon eggs and larvae in the D-Area intake cooling water is not likely because of their demersal (bottom) and adhesive nature. In addition, spawning occurs in the Savannah River during February and March (Matthews and Muska, 1983), before any increased pumping that would be required during the May-to-September mitigation period. Previous studies have found no shortnose sturgeons on the SRP cooling water intake screens, and there is no evidence that juveniles or adults inhabit the intake cove. Moreover, healthy shortnose sturgeon are unlikely to be impinged, given pumphouse intake velocities and sturgeon swimming speeds (Du Pont, 1985b). In addition, the National Marine Fisheries Service (NMFS) has previously concurred in DOE's determination that the population of shortnose sturgeon in the Savannah would not be affected adversely by SRP operations (Oravetz, 1983).

Radiological Releases

Because the cooling water discharge from the D-Area powerhouse does not contain radionuclides, there would be no direct radiological releases or impacts associated with the operation of increased flow with mixing. The

increased flow to Beaver Dam Creek from increased flow with mixing would result in a slight reduction in the concentrations of tritium in the creek, which are due to releases from the moderator rework facility.

Remobilization of radionuclides such as cesium-137 from the Beaver Dam Creek bed would be insignificant, because radionuclides with the potential for remobilization are present only in very minute quantities in the creek bed (Boyns and Smith, 1982; Du Pont, 1981a, 1981b; Du Pont, 1985c; Lower, 1984b; Lower and Hayes, 1984).

4.3.2 DIRECT DISCHARGE TO SAVANNAH RIVER

4.3.2.1 Construction Impacts

Socioeconomics

The direct discharge alternative for the D-Area would involve construction of a new pipeline and discharge system from D-Area facilities to the Savannah River. The construction would be accomplished in approximately 22 months, and would involve a peak construction workforce of 40 persons.

The analysis presented in Section 4.1.1.1 indicates that a large number of construction workers living in the general vicinity of the SRP are expected to become available for employment in the next few years. Because these construction workers already reside in the SRP area, no impacts to local communities and services due to immigrating workers would be expected.

Historic and Archaeological Resources

An archaeological and historic resources survey was conducted that encompassed the specific area west of Beaver Dam Creek that would be disturbed by pipeline construction activities associated with the direct discharge alternative for D-Area. No evidence of archaeological resources was found during the survey; therefore, no impacts are anticipated from implementation of this alternative.

Water Quality and Hydrology

The principal impact to water quality during construction would be some temporary localized increases in suspended solids in the Savannah River and swamp due to runoff and erosion from land areas and to dredging on the river bank. Appropriate engineering construction measures would be utilized to control erosion and drainage.

Some temporary structures (e.g., access roads, cofferdams, berms) might have to be used during the construction of the pipeline from D-Area into the river. These structures would be planned to minimize any disruption of natural water flows by using such measures as bypass channels and culverts. Following construction, the waterways would be restored to their previous state as much as possible. No permanent changes in existing flow patterns in the stream, river, or swamp are anticipated.

Construction of the discharge sparging system along the river banks would require limited dredging through the natural levee separating the Savannah River from the swamp. These activities could require a permit from the U.S. |TC

Army Corps of Engineers. A Section 401 certificate from SCDHEC would also be required to ensure that construction- and operation-related discharges into navigable waters comply with the applicable effluent limitations and water quality standards of the Clean Water Act.

Ecology

An estimated 1 acre of wetlands and 5 acres of uplands would be disturbed by construction of the pipeline and associated rights-of-way from the D-Area plant to the Savannah River. Construction activities are not expected to produce adverse effects on vegetation outside the immediate construction areas. Approximately 4 of the 6 acres that would be affected consist of regenerated loblolly pine and bottomland hardwoods.

BB-3 | During construction, wildlife (e.g., birds, turtles, and small game animals) would leave the immediate area of construction when activities increased. The process of clearing the right-of-way and installing the pipe could result in the loss of some small mammals, such as shrews and mice, and some amphibians and reptiles such as salamanders and snakes. No critical habitats for threatened or endangered species would be affected by the construction of the pipeline, because no critical habitat has been identified in South Carolina. When construction was completed, areas no longer needed for construction would be replanted with appropriate grasses, shrubs, or trees and thus made available for use by wildlife.

Temporary increases in siltation would result in impacts on some benthic organisms and could temporarily affect fish spawning in the immediate area of the discharge structure if construction were to occur during the spawning season. These effects would be temporary, and biota should recolonize after the disturbance ceased or equilibration occurred.

Other Construction Impacts

Solid waste (excluding clearing debris) would be placed in containers for disposal in an approved manner. Because of the proximity of the construction to waterways, special care would be taken to prevent spills of fuels or chemicals. All applicable atmospheric emissions standards would be met during construction.

There would be no significant radiological impacts associated with the installation of a pipeline from the D-Area powerhouse condensers to the Savannah River, because no discharges of radioactivity would occur.

4.3.2.2 Operational Impacts

Socioeconomics

No socioeconomic impacts are expected from the operation of the new pipeline, because maintenance of the pipeline and discharge system would be performed by existing maintenance crews.

Historic and Archaeological Resources

The operation of the direct discharge of cooling water to the Savannah River would not cause any impacts to historic and archaeological resources.

Water Quality and Hydrology

Before SRP operations began in 1952, Beaver Dam Creek is believed to have been an intermittent stream (Jacobsen et al., 1972). The removal of the present condenser cooling water discharge could result in the creek's reverting to its former status, although some of the existing discharges from D-Area would still enter the waterway (e.g., rework area process sewer, miscellaneous powerhouse wastewater, sanitary plant effluent, and ash basin effluent). The total flow from these sources would be about 0.18 cubic meter per second. Overflow from the raw-water basin would be about 0.3 cubic meter per second, but could vary from about 0.1 to 0.8 cubic meter per second. These effluents would continue to meet the State of South Carolina Class B water classification standards; no adverse impact on the creek is expected.

With this alternative heated discharge water would no longer be released to Beaver Dam Creek; therefore, the principal change in existing water quality in the stream would be the reduction in water temperature to ambient levels. Temperatures in some portions of the swamp also would be reduced; however, because much of the flow from Four Mile Creek joins the swamp near the mouth of Beaver Dam Creek, some heat would enter this area until the implementation of a cooling water system for C-Reactor. Additional heat would be released directly to the Savannah River at the discharge points along the effluent pipeline sparging system. The temperature of the discharge is expected to be about 8°C above the ambient temperature of the river at the points of effluent release (see Table 2-8). Outside a small mixing zone, temperatures would meet State water quality criteria and, therefore, there would be no adverse impact on the river.

Nutrient concentrations in Beaver Dam Creek would be somewhat reduced from present levels with this alternative. The concentrations of most nutrients are now higher than those in other unimpacted streams on the SRP site because of the Savannah River water that is circulated through the cooling water system of the powerhouse. Removal of the effluent discharge from the creek, therefore, would lower the nutrient concentrations in Beaver Dam Creek.

The flow in Beaver Dam Creek would be reduced from the present annual average discharge of about 2.6 cubic meters per second to about 0.5 cubic meter per second during normal operations, not including any intermittent flow after rainfall. Water levels and flow in the swamp at the mouth of Beaver Dam Creek would also be reduced, but not as much as in the stream itself because flow from Four Mile Creek would still enter the swamp near the mouth of Beaver Dam Creek. Nonetheless, the diversion of a flow of 2.1 cubic meters per second would result in a lowering of the water levels in this region of the Savannah River swamp. This impact would be evident most of the year, except during the spring or at other times when river flooding inundates much of the swamp adjacent to the Savannah River Plant.

Air Quality and Noise

No significant environmental impacts in air quality or noise levels are expected during operation of the direct discharge cooling system.

This alternative would cause no increase in atmospheric emissions of pollutants; steam generation rates would remain the same; all applicable air quality standards would be met.

Ecology

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Discharge of thermal effluent directly to the river could result in a limited thermal attraction of fish to the immediate area of the diffuser. The most significant impact of this alternative on the ecology of Beaver Dam Creek would be a significant reduction in flow. The upper reaches of the stream would continue to be an intermittent stream. Portions of the creek downstream from the existing discharge canal that are bordered by swamp would consist of interspersed shallow pools and/or slow-moving water. Accordingly, the aquatic habitat available for colonization by fish and macroinvertebrates would be less than at present and would approximate pre-SRP conditions. During winter and spring flooding, portions of the Beaver Dam Creek area would be inundated with Savannah River water and would serve as a spawning and nursery area for resident species of fish (e.g., sunfish, minnows, and darters), as well as migratory species (e.g., blueback herring). However, less spawning and nursery habitat would be available than at present.

Many areas of Beaver Dam Creek that are currently inundated by discharges from D-Area would undergo successional vegetation redevelopment into a more mesic scrub-shrub community. From 1952 through 1974, 412 acres of wetlands were affected in the Beaver Dam Creek floodplain and swamp due to thermal discharges and flooding (Du Pont, 1985b, 1987). The temperature of the effluent began to decrease in 1973 and continued to decline until 1978; a concurrent net reversal of delta canopy loss occurred. During this period, about 5 acres of canopy in the Beaver Dam Creek area were restored, and by 1984 a total of about 30 acres had regrown. Currently, the affected Savannah River swamp canopy of Beaver Dam Creek totals about 382 acres and is recovering at a rate of about 3 acres per year (Du Pont, 1985b, 1987). Implementation of this alternative would allow revegetation to continue, leading to conditions that more or less prevailed prior to 1952.

Entrainment and Impingement

This alternative would not require changes to the intake structures or the receiving water flow rates. Accordingly, the entrainment and impingement rates associated with direct discharge would be similar to those resulting from present operations.

BD-5

Projections of current entrainment and impingement losses, based on ichthyoplankton studies conducted annually at the site from 1983 to 1985 (DOE, 1987a; Appendix C), indicate that operation of D-Area presently results in the estimated loss of an average 1.2×10^6 fish larvae (range: 0.7×10^6 to 1.8×10^6 larvae) and 0.8×10^6 fish eggs (range: 0.5×10^6 to 1.1×10^6 eggs) each year. The principal taxonomic groups affected are the clupeids, centrarchids, and cyprinids.

An estimated average of 1718 fish per year (range: 213 to 4679 fish per year) would continue to be impinged on the intake screens of the 5G pumphouse. The principal species impinged would be the centrarchids and clupeids. The overall impact on the fishery resources would continue to be minimal.

BD-5

Threatened and Endangered Species

The operation of the direct-discharge system would have a significant impact on the habitats of the American alligator and the wood stork by decreasing the flow in Beaver Dam Creek from about 2.6 cubic meters per second under present operating conditions to about 0.2 cubic meter per second. Implementing this alternative would decrease or eliminate nesting habitat for the American alligator and would eliminate any thermal refugia that might have existed during winter months. Foraging habitat for the wood stork would be decreased significantly or eliminated. Beaver Dam Creek essentially would return to its original condition as an intermittent stream.

BB-3

Flood conditions would result only from storm runoff after rains and Savannah River flooding. Based on pump test data (Section 4.3.1.2), it is reasonable to assume that any flooding that occurred in Beaver Dam Creek from surface runoff would be of short duration and that the water level in Beaver Dam Creek swamp would return to its original level within approximately 24 hours after rainfall had stopped.

Because the thermal effluent would be discharged directly to the Savannah River, there would be a small thermal plume at the outfall structure; however, there would continue to be a large zone of passage for all fishes, including the endangered shortnose sturgeon. There would be no significant impacts on the shortnose sturgeon due to entrainment and impingement.

Radiological Releases

Because the cooling water discharge from the D-Area powerhouse does not contain radionuclides, there would be no direct radiological releases from D-Area to the Savannah River. The annual release of tritium from the D-Area Moderator Rework Facility to Beaver Dam Creek, and eventually to the Savannah River, would remain unchanged. The release is a function of the operation of the rework facility and does not depend on the operation of the powerhouse or its mode of discharge. The only effect of the reduced flow in Beaver Dam Creek on tritium releases - resulting from direct discharge from the powerhouse to the Savannah River - would be an increase in its concentration in the creek.

Remobilization of radionuclides such as cesium-137 from the Beaver Dam Creek bed would be insignificant, because radionuclides with the potential for remobilization are present only in very minute quantities (Boyns and Smith, 1982; Du Pont, 1981a, 1981b; Du Pont, 1985c; Lower, 1984b; Lower and Hayes, 1984).

4.3.3 NO ACTION - EXISTING SYSTEM

The no action alternative for the D-Area coal-fired powerhouse would maintain the existing once-through cooling water system that withdraws water from the Savannah River and discharges it to Beaver Dam Creek. Chapter 3 and

Appendix C describe the existing environmental baseline conditions associated with this system. This section summarizes the minor impacts that would not change for the no-action alternative.

4.3.3.1 Water Quality and Hydrology

The mean discharge to Beaver Dam Creek from the D-Area powerhouse would continue to be about 2.6 cubic meters per second (range: 1.2 to 4.5 cubic meters per second) (Du Pont, 1985b, 1987). The water from the creek would mix with part of the flow from Four Mile Creek in the Savannah River swamp before it discharges to the river through the mouth of Beaver Dam Creek (Du Pont, 1985b, 1987).

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Water temperatures in the creek and delta could reach 34°C under extreme summer conditions when ambient river temperatures are about 21°C (see Appendix B, Table B-3). Under average summer conditions, creek and delta temperatures would be approximately 29°C. Comparable winter temperatures would be about 15° to 16°C (Lower, 1984a). The continuation of the existing cooling water discharge in D-Area would meet the Class B water classification standards for temperature most of the time, but would exceed the limit during warm-weather periods and concurrent high powerhouse loadings.

4.3.3.2 Ecology and Wetlands

The aquatic and terrestrial ecology of the Beaver Dam Creek area would continue to be influenced by the heated water discharged from the coal-fired steam plant. Aquatic flora in the creek would be sparse due to the elevated temperatures and flow of the effluent. Thermophilic bacteria and blue-green algae would continue to be the most abundant flora in the main channel (Gibbons and Sharitz, 1974). Riparian vegetation would be dominated by wax myrtle and tag alder. Portions of the Beaver Dam Creek delta would continue to show evidence of revegetation because of the decline of water temperatures, which began in the 1970s (DOE, 1984). More species of macroinvertebrates would occur in Beaver Dam Creek than in the other thermally impacted streams.

In general, fish density would be higher in Beaver Dam Creek than in either Four Mile Creek or Pen Branch, but lower than in the nonthermal streams (Du Pont, 1985b, 1987). The fish species present in the creek in greatest numbers as adults would be mosquitofish, sunfish, and gizzard shad (Bennett and McFarlane, 1983). Relative abundance and species composition would increase toward the creek mouth and swamp, where greater habitat diversity occurs and temperatures are somewhat moderated (Du Pont, 1985b, 1987). Ichthyoplankton in the creek would reflect the adult fish composition.

4.3.3.3 Entrainment and Impingement

BB-3
BD-5

With the no-action alternative, entrainment at the 5G intake would result in the continued loss of an average 1.2×10^6 fish larvae (range: 0.7×10^6 to 1.8×10^6 larvae) and 0.8×10^6 fish eggs (range: 0.5×10^6 to 1.1×10^6 eggs) each year (DOE, 1987a). The principal taxonomic groups that would be affected are the clupeids, centrarchids, and cyprinids.

Impingement of fish on the intake screens of the 5G pumphouse would continue to average 1718 per year (range: 213 to 4679 fish per year; DOE, 1987a). The principal species impinged would be expected to be sunfish and shad.

BB-3
BD-5

4.3.3.4 Threatened and Endangered Species

The area in and around Beaver Dam Creek would continue to provide habitat for a dense population of American alligators. Backwater areas would continue to provide breeding and nesting habitat and probably support a self-sustaining alligator population based on the presence of juvenile and adult individuals in the creek area (Du Pont, 1985b).

BB-3

Endangered wood storks from the Birdsville rookery, which have been observed foraging in the Beaver Dam Creek area since 1982 (Du Pont, 1985b, 1987), should continue to use the area.

BB-3

4.4 CUMULATIVE IMPACTS OF ALTERNATIVE COOLING WATER SYSTEM CONSTRUCTION AND OPERATION

This section describes the cumulative impacts of the construction and operation of the cooling water alternatives for K- and C-Reactors and the D-Area coal-fired powerhouse on surface-water usage, thermal discharges, ecological systems, radiological releases, and air quality. These impacts have been evaluated in conjunction with the releases from other SRP facilities and from major facilities near the Savannah River Plant.

4.4.1 SURFACE-WATER USAGE

The Savannah River Plant withdraws a maximum of 37 cubic meters of water per second from the Savannah River, primarily for use as cooling water. Plant operations consume approximately 2.4 cubic meters per second of this water; the remainder returns to the river via onsite streams.

The existing withdrawal and return rates would remain essentially the same for the once-through cooling-tower alternative. The water consumed by evaporation in each tower would be approximately 0.8 cubic meter per second. The total water withdrawal from the river for the Plant, including once-through cooling towers at both K- and C-Reactors, would be 24 percent of the 7-day, 10-year low flow (7Q10; 159 cubic meters per second) and 13 percent of the average flow (295 cubic meters per second). Only about 3.4 cubic meters per second of the 159-cubic-meter-per-second low flow would be consumed.

TC

The existing withdrawal and return rates would be reduced substantially for the recirculating cooling-tower alternatives. The withdrawal rate of 1.6 cubic meters per second for each reactor would represent a decrease of approximately 9.7 cubic meters per second per reactor from the rate for the existing system. The total SRP withdrawal from the river, including recirculating cooling towers at both K- and C-Reactors, would be about 12 percent of the 7-day, 10-year low flow (7Q10) and about 7 percent of the average flow. As with the once-through tower, the water consumed in the recirculating towers would be about 0.5 cubic meter per second more than that consumed by the existing system.

AO-1
BC-9

For both the direct-discharge and increased-pumping alternatives for D-Area, the withdrawal of river water would be unchanged during normal climatological conditions. During very hot periods, however, the amount of water withdrawn from the river for the increased-pumping alternative would be increased to meet the Class B water classification standard of a minimum instream temperature of 32.2°C; the withdrawal rate for this alternative would increase from 2.6 (existing system) to 4.0 cubic meters per second, resulting in a slightly higher total withdrawal than that discussed above for the once-through and recirculating cooling-tower alternatives. This additional water would return to the river via Beaver Dam Creek, thereby causing no effects to total SRP consumptive surface-water losses.

4.4.2 THERMAL DISCHARGE EFFECTS

4.4.2.1 Onsite Streams and Savannah River Swamp

Cooling water is now directly discharged from the SRP via four streams - Beaver Dam Creek, Four Mile Creek, Pen Branch, and Steel Creek. In addition, overflow from Par Pond enters Lower Three Runs Creek. Beaver Dam Creek receives once-through cooling water from the D-Area powerhouse, and Four Mile Creek and Pen Branch receive once-through cooling water from K- and C-Reactors, respectively. Steel Creek receives cooling water from L-Reactor via a once-through cooling lake and - in its lower reaches - from K-Reactor via Pen Branch and the intervening swamp. The principal cumulative impact of the implementation of alternative cooling water systems at K- and C-Reactors and the D-Area powerhouse would be a reduction in the total amount of waste heat dissipated to all onsite streams and the Savannah River swamp. A cumulative impact that would result from this reduction in thermal discharge would be the revegetation of surrounding areas through natural plant succession and, thus, an increase in total wetland habitat. In addition, a reduction in thermal discharge would allow previously affected thermal streams to be recolonized by fish and macroinvertebrates and would provide additional spawning habitat for fish. A zone of passage for anadromous fish and other aquatic organisms in SRP thermal streams and the Savannah River swamp would be provided, thereby creating more available habitat for these organisms in completing their life cycles.

Implementation of the once-through cooling-tower alternative would result in thermal plumes from C-Reactor and the D-Area powerhouse interacting within the Savannah River swamp. However, thermal performance studies have indicated that this interaction would reduce thermal effects in this area of the swamp. In addition, the thermal discharge from K- and L-Reactors would interact via Pen Branch and Steel Creek in the Savannah River swamp with the implementation of the once-through cooling-tower alternative. Thermal performance studies indicate that temperatures in Pen Branch would be about 2°C cooler than those in Steel Creek at their confluence during winter, when thermal plumes could be most evident.

4.4.2.2 Savannah River

In the vicinity of the Savannah River Plant, the Savannah River receives thermal discharges from the Urquhart Steam Station at Beech Island, South Carolina, as well as from the Plant. In addition, the Alvin W. Vogtle Nuclear

Power Plant, near Hancock Landing, Georgia, across the river from the Plant, uses natural-draft cooling towers to dissipate waste heat before discharging to the river at temperatures below 33°C (NRC, 1985). TC

As the result of water storage in Clarks Hill Reservoir above Augusta, Georgia, and its hypolimnetic discharge, the temperature of the Savannah River is as much as 8°C below the temperature that would normally occur during the summer if the reservoir did not exist (Neill and Babcock, 1971). The temperature of the river generally increases naturally as the water flows from Clarks Hill Reservoir past the SRP. The South Carolina Electric and Gas Company's Urquhart Steam Station, located above the Savannah River Plant, discharges about 7.4 cubic meters per second of cooling water at temperatures as high as 6°C above ambient river temperatures. The Vogtle Nuclear Power Plant would discharge about 0.7 cubic meter per second of cooling water to the Savannah River with a winter thermal plume 2 meters wide extending 9.8 meters downstream from the single-port discharge pipe (NRC, 1985). This winter thermal plume would not extend beyond its permitted mixing zone or interact with SRP or Urquhart discharges.

The cumulative impact upon the Savannah River with the implementation of alternative cooling water systems at K- and C-Reactors and the D-Area powerhouse would be a reduction in the total amount of waste heat discharged to the Savannah River via onsite streams. These discharges would not interact with Urquhart or Vogtle generating stations. Removal of SRP thermal discharges would result in an increased zone of passage in the Savannah River for anadromous fish and other aquatic organisms and would allow for more available habitat for aquatic organisms in the river.

Implementation of the direct discharge alternative to the Savannah River for D-Area and implementation of once-through cooling towers for K- and C-Reactors would result in winter and spring plumes entering the Savannah River, raising the temperature in the immediate area of the confluence of the streams with the river more than 2.8°C above ambient. Even though there would be a thermal plume present during the winter and spring at the immediate confluences of the mouths of Beaver Dam, Four Mile, and Steel Creeks, and the Savannah River, it would not create a thermal blockage of the river. Also, a zone of passage would continue to be available for anadromous fish and other aquatic organisms.

4.4.3 ECOLOGY

4.4.3.1 Terrestrial Areas

The cumulative impact of the preferred alternative cooling systems for K- and C-Reactors and D-Area would disturb no more than about 60 acres of uplands, consisting of immature slash pine and reforested upland pine/hardwood, some open fields, and a relatively small area of bottomland hardwoods. BB-3 BC-9

In addition, the cumulative impacts from salt deposition from the operation of recirculating cooling towers at both K- and C-Reactors would result in an estimated 22.7 kilograms per acre per year at a distance of 0.5 kilometer from each tower. These rates represent the highest values associated with any of the various combinations of alternatives and are much less than those that can

cause reduced productivity of plants (Mulchi and Armbruster, 1981; INTERA, 1980). Beyond 2 kilometers (see Figure 4-4), the deposition rates decline even more with distance from the towers. Therefore, no significant cumulative impacts are expected with this combination of alternatives.

4.4.3.2 Onsite Streams and Savannah River Swamp

The cumulative effects of the construction of any combination of the cooling water alternatives on the aquatic environment would be minimal because the reaches of Pen Branch and Four Mile Creek in the vicinity of the proposed activities are presently sparsely inhabited by aquatic organisms due to existing thermal stress. No construction is required for the increased-flow-with-mixing alternative for D-Area, and the direct-discharge system would have minimal impact due to its proposed location along previously disturbed areas and construction practices which would minimize turbidity and siltation.

The principal cumulative impact of the operation of cooling towers for K- and C-Reactors and either increased flow or direct discharge at D-Area would be the reduction of water temperatures in onsite streams and the adjacent swamp to ambient or near-ambient levels. Among the most important effects of removing the existing thermal stress from these environments would be the discontinuation of the loss of wetlands along the waterways (e.g., the combined loss in 1984 due to K- and C-Reactor operations was about 54 acres). It is expected that some wetland areas previously damaged or destroyed would revegetate successively due to the lowered water temperatures. However, increased flow and intermittent flooding (with the once-through towers and the increased-flow-with-mixing alternatives) would still limit wetland revegetation in some locations. The continued existence of open canopy areas would benefit some species (e.g., waterfowl and wood stork). There would also be a beneficial effect of the lower water temperatures on aquatic biota. Foraging and spawning habitats and zones of passage in the streams and swamp that were previously inaccessible to fish due to the heated discharge would now be open to these organisms. Populations in headwater areas above the reactor discharge points would no longer be isolated from the main streams, the swamp, and the Savannah River. Also, the potential for cold shock in the thermal portions of the streams and swamp would be reduced. The cumulative effect of this would be to increase the area of aquatic habitat in SRP streams and the adjacent swamp and thereby increase the populations of fishes and other aquatic organisms in comparison to existing conditions. Productivity of the Savannah River might increase in this area of the river due to increased contributions of progeny from the onsite streams and swamp.

The cumulative effect of the installation of recirculating cooling towers at K- and C-Reactors and of direct discharge of D-Area effluent to the Savannah River would have somewhat less positive impacts. This combination of alternatives would greatly decrease thermal stress in the onsite streams and portions of the adjacent swamp; however, they would also cause significant decreases in flow in these waterways. Therefore, although these alternatives would provide some increases in available aquatic habitat compared to present conditions, the beneficial effects would be less than those experienced with the once-through towers and increased-flow-with-mixing options due to lowered water levels in the streams and some portions of the swamp. These lowered

water levels could be more conducive to wood stork foraging habitat in Four Mile Creek and Pen Branch, but would totally eliminate the foraging habitat in Beaver Dam Creek.

4.4.3.3 Savannah River

The cumulative effect on the Savannah River of the implementation of cooling towers would be a reduction in the total amount of waste heat discharged from the onsite streams. This would increase the size of the zones of passage in the river adjacent to the Savannah River Plant and thereby would allow greater flexibility in movement of anadromous fish and other aquatic organisms through that section of the river.

The direct-discharge alternative for D-Area, combined with once-through towers for the two reactors, would result in thermal plumes entering the river in winter and spring near the confluences with Beaver Dam Creek, Four Mile Creek, and Steel Creek. The maximum temperature above ambient, which would be about 2.8°C within these plumes, would not create a significant thermal barrier in the river or cause any other adverse impact on fishes or other aquatic organisms.

4.4.3.4 Entrainment and Impingement

The cumulative entrainment and impingement impacts of some combinations of the cooling water alternatives would remain the same as those for present conditions; for other combinations, there would be either a reduction or an increase in these effects.

The implementation of a once-through cooling-tower system for K- and C-Reactors and direct discharge for D-Area would not change existing levels of entrainment and impingement significantly. At present, the combined total loss of ichthyoplankton due to the operation of these three facilities averages 18.8×10^6 fish larvae and 10.1×10^6 fish eggs annually, or an average of 11.8 percent of the ichthyoplankton passing the SRP intakes, based on 1983-1985 studies (see Table C-24; DOE, 1987). Cumulative impingement currently averages 7603 fish per year (DOE, 1987). In addition, the species composition of the fishes lost to entrainment and impingement would not change with this combination of alternatives. Assuming that K- and C-Reactors would operate at levels comparable to that for L-Reactor, additional average entrainment losses of 8.8×10^6 fish larvae and 4.6×10^6 fish eggs (or an average of 5.4 percent of the ichthyoplankton passing the SRP intakes; see Table C-24) and additional average impingement losses of 2942 fish would occur annually as a result of the operation of these facilities. Accordingly, cumulative annual losses from entrainment and impingement due to the operation of these four facilities would average 27.6×10^6 fish larvae and 14.8×10^6 fish eggs (or an average of 17.2 percent of the ichthyoplankton passing the SRP intakes; see Table C-24) and 10,545 fish, respectively.

BD-5

The implementation of a recirculating cooling-tower system in combination with direct discharge at D-Area would lower the cumulative effects of both entrainment and impingement. The reduced flow requirements for the cooling water systems of the two reactors would result in a decline in annual entrainment losses from current combined levels to about 3.8×10^6 fish

larvae and about 2.1×10^6 fish eggs per year. Cumulative impingement losses would decrease to about 2571 fish per year. Species composition of fish lost to entrainment and impingement would not change with this combination of alternatives. Cumulative annual losses from entrainment and impingement due to the operation of these facilities plus L-Reactor would average 12.6×10^6 fish larvae and 6.7×10^6 fish eggs and 3369 fish, respectively.

BD-5

The implementation of a once-through cooling-tower system for K- and C-Reactors in combination with the increased-pumping alternative for the D-Area powerhouse would increase entrainment and impingement in proportion to the increase in cooling water withdrawn for the powerhouse. Cumulative entrainment losses would increase to about 18.84×10^6 fish larvae and 10.12×10^6 fish eggs per year, while cumulative impingement losses would increase to about 7665 fish per year. Cumulative annual losses from entrainment and impingement due to the operation of these facilities plus L-Reactor would average 27.64×10^6 fish larvae and 14.77×10^6 fish eggs and 10,608 fish, respectively.

The implementation of a recirculating cooling-tower system in combination with increased pumping at D-Area would result in a net reduction in cooling water withdrawal and a proportional decrease in entrainment and impingement levels. Cumulative entrainment losses would decrease to approximately 3.84×10^6 fish larvae and 2.12×10^6 fish eggs per year, while impingement would decrease to about 2683 fish per year. Cumulative annual losses from entrainment and impingement due to the operation of these facilities plus L-Reactor would average 12.64×10^6 fish larvae and 6.77×10^6 fish eggs and 5626 fish, respectively.

4.4.3.5 Threatened and Endangered Species

The endangered red-cockaded woodpecker, bald eagle, and shortnose sturgeon would not be affected by any of the alternatives individually and would not be affected by their combined construction and operation.

BB-3

At present, the American alligator does not inhabit Pen Branch or Four Mile Creek because of the high water temperatures associated with reactor operations. The implementation of once-through cooling towers would enable the alligator and other organisms to inhabit these thermal areas. However, fluctuating water levels and flow rates could destroy alligator eggs, nests, and hibernation sites. The recirculating cooling-tower alternatives would enable the alligator to inhabit these areas; however, because of the marked decrease in flows, the inundation of eggs, nests, and hibernation sites would be improbable. The implementation of the increased-flow-with-mixing alternative at D-Area would not appreciably change the value of the existing alligator habitat in Beaver Dam Creek. Therefore, the cumulative impact of any combination of these alternatives would be a general increase in the available habitat for the alligator in these areas.

The implementation of the direct-discharge alternative for D-Area in combination with either cooling-tower alternative would have a deleterious cumulative impact on the alligator. The direct-discharge alternative for

D-Area would reduce the existing alligator habitat in Beaver Dam Creek by removing the beneficial thermal environment that now exists and by significantly lowering water levels and flows in the stream.

The implementation of once-through cooling towers would improve existing habitat for the endangered wood stork, but the availability of foraging habitat would be restricted due to water depths and flow rates. Recirculating cooling towers would cause significantly reduced discharge rates and should enhance the availability of wood stork foraging habitat. The increased-flow-with-mixing alternative for D-Area would decrease the availability of wood stork foraging habitat during periods of increased flow.

BB-3

There would be a cumulative loss of foraging habitat for the wood stork with any combination of alternative cooling water systems that included direct discharge from the D-Area powerhouse. This alternative would reduce the water levels in Beaver Dam Creek and thereby reduce or eliminate the value of this area for foraging by the wood stork.

4.4.4 RADIOLOGICAL RELEASES

Nuclear facilities within an 80-kilometer radius of the SRP include operating or planned SRP facilities, the two-unit Alvin W. Vogtle Electric Generating Plant (one unit operating, the other still under construction), the Barnwell Nuclear Fuel Plant (not expected to operate), and the Chem-Nuclear Services, Inc., low-level radioactive disposal site. The existing and planned operations of these facilities were reviewed to determine the potential cumulative radiological effects of all the facilities operating together with the alternative cooling water systems being considered for K- and C-Reactors.

SRP facilities operating include four production reactors, two chemical-separations areas, a fuel-fabrication facility, waste management facilities, and other support facilities. Future projects include construction and operation of a Fuel Materials Facility (FMF) for producing fuel forms for the naval reactor program, the Fuel Production Facility (FPF) for recycling enriched uranium used as reactor fuel, and the Defense Waste Processing Facility (DWPF) for immobilizing high-level radioactive wastes stored in tanks at the Savannah River Plant. The FMF, the FPF, and the DWPF are not expected to become operational until the late 1980s.

The Alvin W. Vogtle Nuclear Power Plant is being constructed by the Georgia Power Company near the southwestern border of the Savannah River Plant across the Savannah River. The first unit of this two-unit power plant became operational in June 1987. The second unit for the Vogtle Power Plant is not expected to reach full operation until the early 1990s.

TC

The Barnwell Nuclear Fuel Plant is located adjacent to, and east of, the Savannah River Plant. The owners of this facility, Allied-General Nuclear Services, have announced that they do not plan to operate this plant. The normal operation of the Chem-Nuclear Services, Inc. low-level radioactive disposal site does not entail discharges of low-level radioactive material to surface waters or to the atmosphere.

The cumulative offsite radiation dose, therefore, is the sum of the doses above natural background from SRP operation with four reactors and their

support facilities, the planned FMF, FPF, and DWPF, and the Vogtle Nuclear Power Plant. The doses associated with two of the SRP reactors, K and C, depend on the alternative cooling water system implemented.

TE

The tables in this section list effective whole-body doses for the offsite, maximally exposed individual and collective effective whole-body doses for the offsite population. The text compares these doses with applicable limits and with natural background radiation. Appendix G contains detailed individual and collective doses for all age groups and important organs due to releases from nuclear facilities on, and within 80 kilometers of, the Savannah River Plant. Essentially all the collective dose results from operation of SRP facilities. These facilities also contribute approximately half the effective whole-body dose to the maximally exposed individual.

Table 4-24 presents the cumulative doses assuming present cooling water systems for K- and C-Reactors (existing operation). The doses shown are for the year 2000, when it is expected that all described facilities will be in operation and when radioactive releases from L-Reactor will have reached an equilibrium.

Table 4-24. Cumulative Effective Whole-Body Doses with Present Cooling Water Systems (Existing Conditions) for K- and C-Reactors

	Maximum individual (mrem/yr)	Collective (person-rem/yr)
Adult	3.25	80.7
Teen	2.64	
Child	1.94	
Infant	0.94	

Table 4-25 presents the cumulative doses assuming a once-through cooling tower for each of K- and C-Reactors - the preferred cooling alternative. These doses represent the sum of existing operation doses and changes in doses associated with operation of once-through cooling towers for K- and C-Reactors.

Table 4-26 presents the cumulative doses assuming recirculating cooling towers for K- and C-Reactors. The use of recirculating cooling towers results in the largest change in doses associated with operation of K- and C-Reactors.

The summary dose tables show that existing operations result in the highest cumulative doses, whereas recirculating cooling towers result in the lowest cumulative doses. The decrease in doses associated with the recirculating cooling towers is greater than that for once-through cooling towers. While other combinations of cooling systems can be chosen, for example, a once-through cooling tower for the C-Reactor combined with recirculating cooling towers for the K-Reactor, the doses presented represent bounding values.

Table 4-25. Cumulative Effective Whole-Body Doses with a Once-Through Cooling Tower for K- and C-Reactors

	Maximum individual (mrem/yr)	Collective (person-rem/yr)
Adult	3.25	80.6
Teen	2.64	
Child	1.94	
Infant	0.94	

Table 4-26. Cumulative Effective Whole-Body Doses with Recirculating Cooling Towers for K- and C-Reactors

	Maximum individual (mrem/yr)	Collective (person-rem/yr)
Adult	3.06	79.6
Teen	2.49	
Child	1.88	
Infant	0.94	

BC-22

The maximum cumulative individual doses are well below the average total-body dose of 93 millirem per year from natural radiation received by an individual living near the SRP site. The doses are also lower than the DOE limits of 100 millirem per year from all pathways and 25 millirem per year to the total body from the air pathway. The collective doses are also much lower than the 109,000 person-rem per year received from natural radiation by the population living within 80 kilometers of the Savannah River Plant and the Beaufort-Jasper and Port Wentworth drinking-water populations.

Table 4-27 lists the health effects associated with the cumulative-dose impacts for each of the alternative cooling water methods discussed above.

4.4.5 AIR QUALITY

The cumulative impacts of K- and C-Reactor on air quality are evaluated and presented below. Two combinations of cooling-tower systems were considered to predict potential maximum impacts. These combinations are as follows:

1. Once-through towers at both K- and C-Reactors
2. Recirculating towers at both K- and C-Reactors

Table 4-27. Cumulative Health Effects

Alternative	Cancer fatalities per year	Genetic disorders per year
Existing operations	0.0110	0.0198
Operations with a once-through cooling tower for each of the C- and K-Reactors	0.0110	0.0198
Operations with recirculating cooling towers for each of the C- and K-Reactors	0.0109	0.0195

The second combination, consisting of recirculating towers at both K- and C-Reactors, produced higher impacts and maximum impacted areas; therefore, this combination is described further in the following paragraphs.

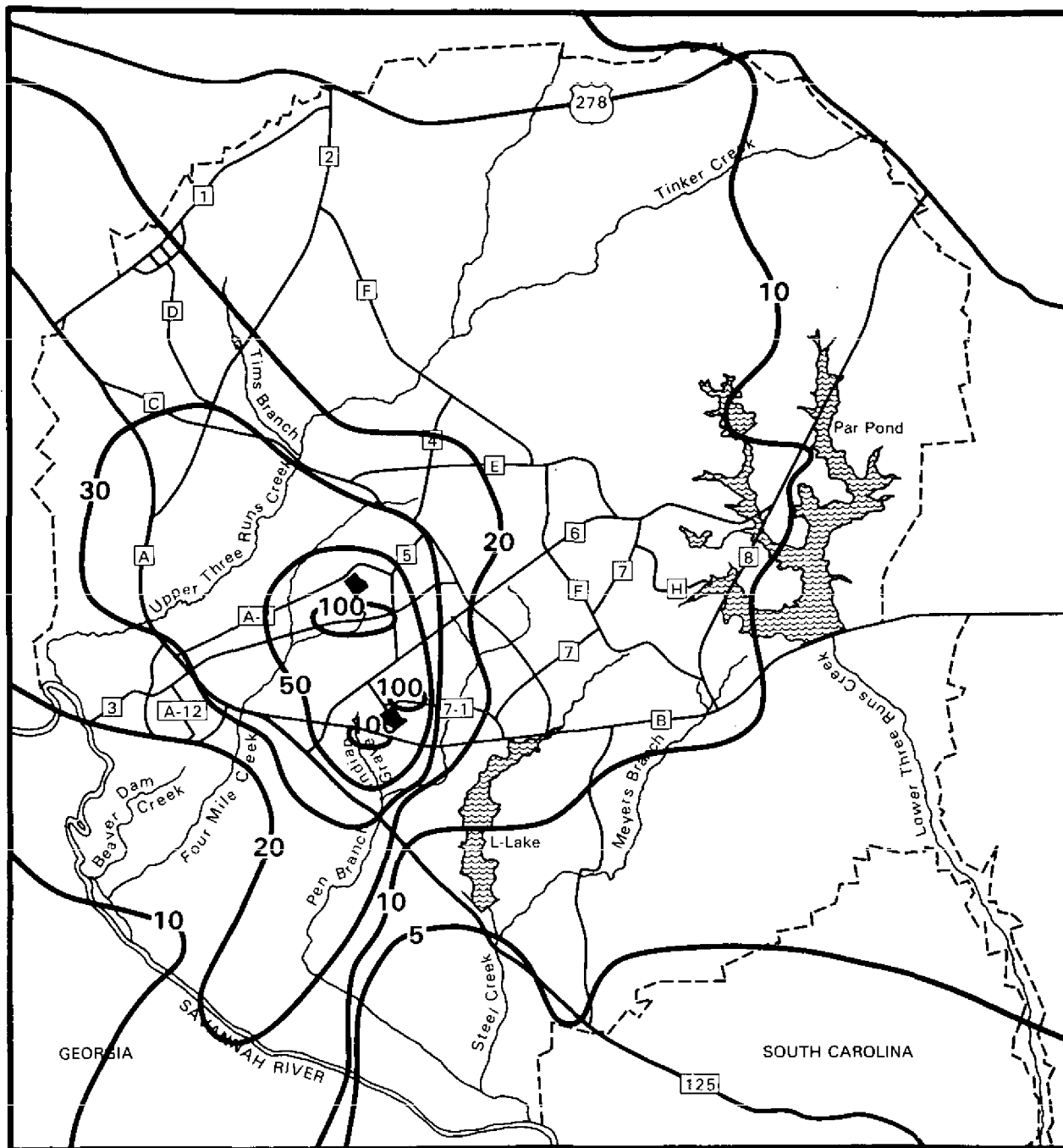
BC-22 The combined calculated maximum annual-mean frequency of reduced ground-level visibility to less than 1000 meters, due to the operation of recirculating cooling towers at both the K- and C-Reactors would be approximately 4 hours per year at 8 kilometers northwest of the C-Reactor towers. The calculated annual-mean frequencies of reduced ground-level visibility to less than 1000 meters would be less than 3 hours per year within 2 kilometers of each tower.

BC-22 Because the K- and C-Reactors are about 4.8 kilometers apart, the maximum ice accumulations within 0.4 kilometer of the towers and their frequencies would be the same as those presented in the individual analyses. Figure 4-3 shows the isopleths of frequency of occurrence of elevated visible plumes for recirculating cooling towers at both K- and C-Reactors. The calculated mean maximum occurrence of visible plumes would be 100 hours per year at 0.6 kilometer from the K- and C-Reactor cooling towers. The frequency of visible plumes would be approximately 50 hours per year within 2 kilometers of each tower system in all directions.

BC-22 Figure 4-4 shows the isopleths of annual solids deposition due to the operation of recirculating cooling towers at both K- and C-Reactors. The estimated maximum annual total-solids deposition would be 22.7 kilograms per acre per year at a distance of 0.5 kilometer from each tower.

4.5 UNAVOIDABLE/IRREVERSIBLE IMPACTS OF ALTERNATIVES

The following sections describe impacts of the alternative cooling water systems that cannot be avoided by reasonable mitigation measures. They also describe irreversible and irretrievable commitments of resources and short-term uses and long-term environmental implications for the alternative cooling water systems.



BB-3
BC-9

Figure 4-3. K- and C-Reactor Recirculating Towers, Frequency of Occurrence of Elevated Visible Plumes, Hours/Year

BB-3
BC-9

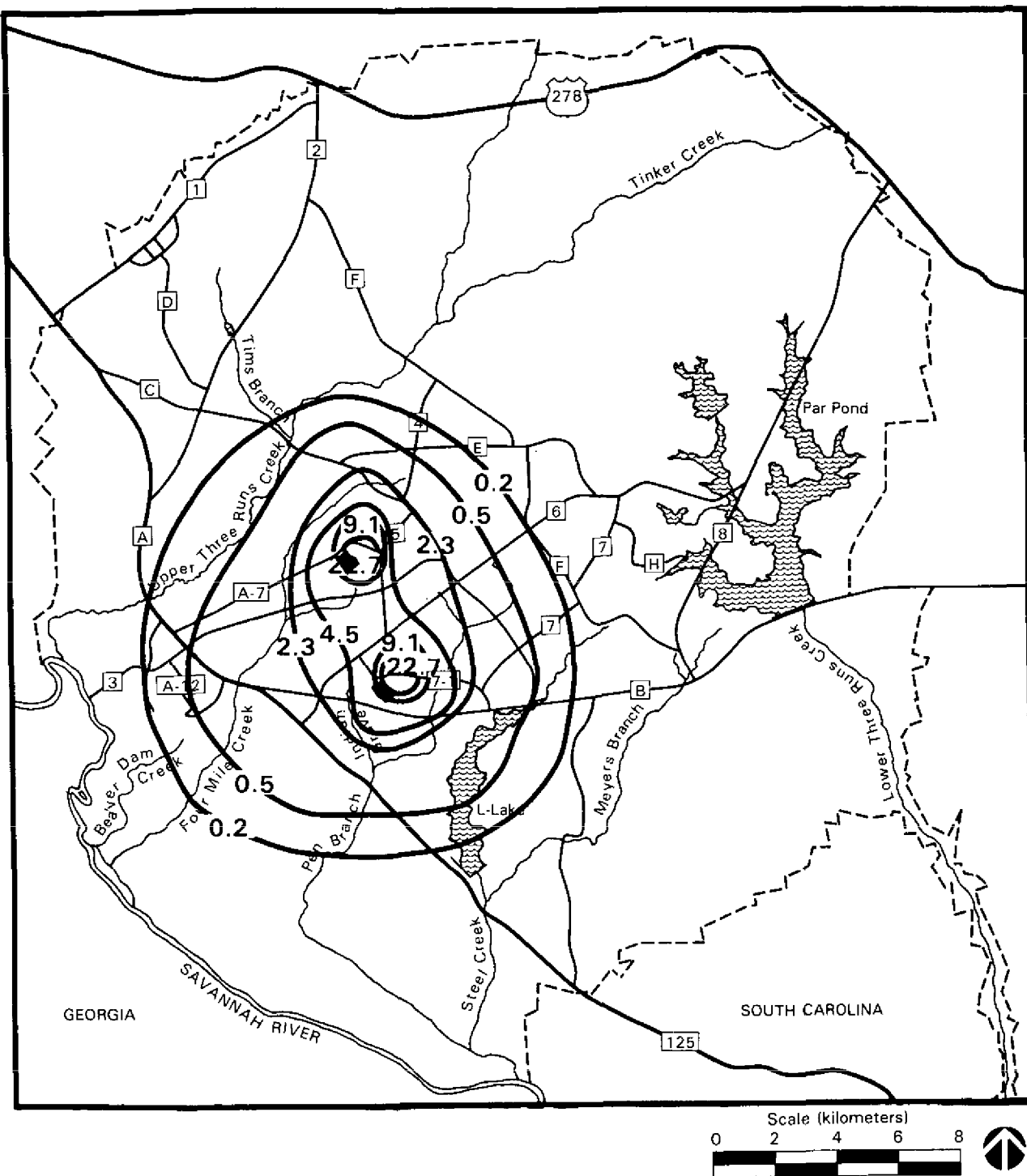


Figure 4-4. K- and C-Reactor Recirculating Towers, Total Solids Deposition, Kilograms/Acre-Year

4.5.1 UNAVOIDABLE ADVERSE IMPACTS

For the once-through cooling towers for K- and C-Reactors, annual entrainment (26.8×10^6 eggs and larvae) and impingement (5884 fish) losses would be similar to those resulting from current operations. With the implementation of once-through cooling towers, the streams would still be subjected to variable flows, thereby limiting reestablishment of upstream wetland communities along both creeks.

The implementation of the gravity-feed, once-through, cooling-tower alternative would result in disturbance of approximately 25 and 35 acres of uplands for K- and C-Reactors, respectively, as a result of construction and the relocation of facilities.

With the implementation of the recirculating cooling-tower alternatives for K- and C-Reactors, cooling water discharge flows would be reduced from 11.3 to 1.1 cubic meters per second, resulting in reduced habitat area for spawning and foraging. Construction and relocation of facilities would disturb approximately 50 and 60 acres of uplands for K- and C-Reactors, respectively.

BC-10
BC-19
BD-3

The increased-flow alternative for the D-Area powerhouse would increase flow to 4.0 cubic meters per second during extreme summer conditions. The expected increase in impingement (additional loss of 113 fish per year) and entrainment (about 6.0×10^4 eggs and larvae) due to increased flow through the 5G pumphouse would be small, and the overall impact would be minimal because entrainment and impingement rates are low during the summer. Temporary increased flow during the summer would increase aquatic habitat. However, wildlife habitat would be reduced and associated wildlife would be displaced temporarily during these intermittent periods of increased pumping. Approximately 4 acres each of uplands and wetlands would be inundated temporarily because of intermittent flooding from increased flow.

TC

The increase in pumping would also result in a temporary increase in the erosion of the stream channel; as a result, increased siltation could occur. Increased pumping could be required during the peak spawning period (May-June) of fish in Beaver Dam Creek. The expected erosion and the resulting siltation would equilibrate rapidly under an increased-flow regime.

The implementation of the direct-discharge alternative for the D-Area powerhouse would significantly alter the existing aquatic community of Beaver Dam Creek because of the reduced stream flow downstream from the discharge canal. Portions of the creek that currently are bordered by swamp would consist of shallow pools or slow-moving water. The reduced flows would also adversely affect the habitat of the currently abundant and reproducing American alligator population. In addition, the Beaver Dam Creek area is sometimes utilized by the wood stork for foraging habitat. Discharge of thermal effluent into the river rather than into the creek would reduce the area of suitable foraging habitat and could impact this species in this area. Approximately 5 acres of uplands and 1 acre of wetlands would be impacted by the construction of the discharge pipeline.

4.5.2 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

Resources that would be irreversibly and irretrievably committed during operation of the cooling water alternatives include (1) materials that cannot be recovered or recycled and (2) materials consumed or reduced to unrecoverable forms. Increased cooling water withdrawal from the Savannah River for the D-Area increased-flow alternative would require additional energy consumption. Irretrievable energy use for pumphouse operations would increase by about 6 percent of the level of current operations. There would not be any additional energy requirements under the direct-discharge alternative.

4.5.3 SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

The short-term effects of the cooling water alternatives would include the loss of upland sites for their natural productivity. Approximately 25 and 35 acres of upland areas would be required for construction and relocation activities for the once-through towers and 50 and 60 acres for the recirculating towers, respectively, for K- and C-Reactors. The short-term effects of the D-Area increased-flow and direct-discharge alternatives would include the unavailability of upland and wetland areas for natural productivity. Approximately 4 acres each of uplands and wetlands would be affected by the increased-flow alternative. For the direct-discharge alternative, the impacted areas would include 5 acres of uplands and 1 acre of wetlands. In the long term, the upland vegetation and wetlands could become reestablished through the process of natural selection.

4.6 COMPARISON OF ALTERNATIVES FOR K- AND C-REACTORS AND D-AREA

TC This section contains a summary comparison of the once-through cooling towers, the recirculating cooling towers and the no-action (continuation of present operations) alternatives for the K- and C-Reactors and the increased flow with mixing, direct discharge, and no-action alternatives for the D-Area powerhouse. For each of the three facilities, selection of the no-action alternative would result in a continuation of present cooling water discharges that would not comply with the State of South Carolina's Class B water classification standard of a maximum instream temperature of 32.2°C. The construction and operation of either once-through or recirculating towers for K- and C-Reactors and implementation of either increased flow with mixing or construction and operation of direct discharge to the Savannah River for the D-Area powerhouse would result in discharges that would comply with this standard. Construction and operation of once-through or recirculating cooling towers for K- and C-Reactors and implementation of increased flow with mixing for the D-Area powerhouse would also require the conduct of Section 316(a) studies to determine whether a balanced biological community would be maintained, because discharges from these alternatives would exceed the State of South Carolina's Class B water classification standard of a maximum instream temperature rise above ambient of 2.8°C. The following comparison discusses the major differences that would occur from the implementation of each of the alternatives.

TC For the various cooling water alternatives, the following relative rankings of future wildlife effects were determined from the Habitat Evaluation Procedures Analysis (Mackey et al., 1987). Effects to terrestrial wildlife from

construction of the once-through and recirculation cooling towers were considered to be essentially equal, since in both cases either type of tower would be constructed at the same location, and pipeline and other support facilities would affect essentially the same locations. Small stream fish species benefit more from the recirculation alternative in the upper reaches of the creeks. In the middle and lower stream reaches, species such as the catfish and sunfish benefit more from the once-through alternative. In the deep swamp environment, those fish which are more likely to use the swamp during the spawning period benefit more from the recirculation alternative. In the Savannah River swamp, wading birds benefit more from the recirculation alternative. Overwintering waterfowl such as the mallard benefit more either from the present SRP operations or from the once-through cooling tower. The once-through and no action alternatives would maintain the existing "marsh" type environment in the swamp for wintering waterfowl or permit expansion of this type of habitat.

TC

4.6.1 ALTERNATIVES FOR K-REACTOR

Either of the two cooling-tower alternatives would significantly reduce the thermal impacts in each respective stream and the Savannah River swamp. The major environmental difference between these alternatives is that the recirculating cooling towers would withdraw less water from the river (about 1.6 cubic meters per second) and release less to the creek (about 1.1 cubic meters per second) than the once-through tower (about 11.3 and 10.5 cubic meters per second, respectively). This would result in reduced entrainment losses of fish eggs and larvae and reduced impingement losses of adult and juvenile fish with the recirculating towers. The reduced flows in Pen Branch and Four Mile Creek and their deltas would also result in successional re-establishment of a greater amount of wetlands than would occur with the once-through cooling-tower alternative; on the other hand, the lower flow would also reduce the existing amount of aquatic habitat in the streams and parts of the swamp than would occur with the once-through tower.

Both alternatives would allow the reestablishment of aquatic fauna and floral communities spawning and foraging in presently uninhabited areas. However, the once-through cooling-tower alternative would exhibit a greater amount of water-level fluctuation, causing some stress to aquatic organisms. Implementation of recirculating cooling towers would reduce thermal effects over what would occur with once-through towers, except that flooded habitat area would be smaller. Most aquatic communities would benefit from the reduced flow and decreased magnitude of water level fluctuations with implementation of a recirculating system. Either alternative would exhibit no potential for cold shock, as the maximum weekly average temperature (MWAT) criteria (EPA, 1977) for winter shutdowns would be met. Dissolved solids concentrations in the discharge would be higher with the recirculating alternative because of cycles of concentration; however, total suspended solids discharge would be greatly reduced.

BB-3

Although once-through cooling towers would improve American alligator (which has been classified as threatened due to "similarity of appearance") habitat over existing conditions, fluctuating water levels and high flow rates could destroy nests, eggs, and hibernation sites. This alternative would also minimize the availability of preferred foraging habitat for the endangered wood stork. Implementation of the recirculating cooling tower would greatly

BB-3

improve the habitat quality for the American alligator and the wood stork. Because of the reduced flow, eggs, nests, and hibernation sites of the American alligator should not be adversely affected.

The impacts of both systems on air quality would be similar; however, because the recirculating cooling-tower system includes two towers operated in series with 2.5 cycles of concentration, the maximum ice accumulation near the towers would be greater for the recirculating system (7 mm versus < 1mm), as would the maximum annual deposition of total solids (2.2 kilograms per acre per year at 2.0 kilometers of the tower versus 0.15 kilogram per acre per year for the once-through tower). Because these deposition rates are far below the levels that can cause reduced vegetation productivity (83 kilograms per acre per year), no impacts on vegetation or wildlife are expected from either cooling-tower alternative.

TC

The operation of the once-through cooling tower would not cause any significant changes in the remobilization of radionuclides contained in the Pen Branch or Four Mile Creek streambeds, because flows in these streams would remain essentially unchanged. The operation of recirculating towers for both K- and C-Reactors would result in a calculated decrease of about 0.33 curie of cesium released to the Savannah River over a year due to the reduced flow. The implementation of either the once-through cooling tower or recirculating cooling towers would slightly reduce the radiological doses to the maximum individual and the 80-kilometer regional population, compared with the existing direct-discharge system, which are presently well within standards. The decrease in maximum individual and collective (population) doses, however, would be greater for recirculating cooling towers than for once-through towers.

Tables 4-28, 4-29, and 4-30 compare these alternatives, along with the expected natural state of Pen Branch within 15 years if reactor operations cease, for Reaches 1, 2, and 3, respectively, of that stream. The division of the Pen Branch watershed into these reaches was based on the presence of distinct stream gradients. These comparisons were made to assess the potential impacts of the alternatives on discrete reaches and the ability of the entire Pen Branch system to exhibit and maintain a balanced biological community. The following paragraphs describe potential effects of the alternatives on the Pen Branch system. (Similar effects should occur on Four Mile Creek for C-Reactor.)

BB-3

Impacts On Reach 1

Reach 1 extends from the K-Reactor outfall down Indian Grave Branch to its confluence with Pen Branch and on to SRP Road A; it encompasses approximately 1 percent (11 of 1100 acres) of the portion of the Pen Branch system that is influenced by K-Reactor cooling water discharges, as utilized for the HEP analysis (Mackey et al., 1987). In this reach, the stream is highly channelized and has its highest gradient, water temperatures, and flows.

With the no-action alternative, highly thermally tolerant species of algae would be the only biota to occur, in limited areas. No spawning activity would occur during reactor outages; limited spawning could occur during long reactor shutdowns, but the success of the spawn would be unsure.

Table 4-28. Comparison of Potential Environmental Impacts in Reach 1^a of Pen Branch System
(page 1 of 2)

Parameter	Alternative cooling water system			
	No action	Once-through cooling tower	Recirculating cooling towers	Natural stream ^b
Flow (variation), m ³ /sec	11.3 (1-11.3)	10.5 (1-10.5)	1 (0.2-1)	0.03 (natural)
Temperature (°C) Maximum/ ΔT	75/48	32/11	30/6	27/0
Vegetation				
Aquatic	Thermally tolerant algae only.	Limited macrophyte development due to high flows.	Increased macrophyte development, but less available habitat compared to once-through system due to lower flows.	Less available habitat, greater macrophyte species diversity, than recirculating system due to low natural flows.
Riparian	Not present due to high temperatures.	Limited development and distribution due to high flows.	Major increase in available habitats; shrub/herb community; greater species diversity than once-through system.	Highest species diversity; invasion by some nonwetland species.
Macroinvertebrates	Not present due to high temperatures.	Limited abundance and diversity due to flows; early emergence due to ΔT greater than 5°C; stranding could occur due to changing flow rates from reactor operations.	Less available habitat than once-through system, comparable or higher density; greater diversity, reduced potential for early emergence, little chance of stranding due to more stable flows.	Least available habitat due to reduced water volume compared to recirculating system. Highest species diversity, no potential for early emergence.

BB-3

Table 4-28. Comparison of Potential Environmental Impacts in Reach 1^a of Pen Branch System
(page 2 of 2)

Parameter	Alternative cooling water systems			
	No action	Once-through cooling tower	Recirculating cooling towers	Natural stream ^b
Fish	Limited utilization by heat-tolerant mosquitofish during reactor outages; no spawning by any species due to excessive water temperatures; however, limited spawning could occur during long shutdowns; not utilized by anadromous and/or riverine species.	Presence of species with high flow tolerance (i.e., minnows, suckers, darters); limited spawning due to fast flow, high gradient, and channelized banks. Limited utilization by anadromous or riverine species.	Maximum development of limited fish habitat and communities; highest fish biomass potential for this reach; higher spawning per unit area than once-through system due to reduced flows. However, access to this reach by fish from downstream reaches 2 or 3 is unlikely due to reduced flows, shallow water depth, and development of dense stands of aquatic vegetation in these reaches.	Less available habitat due to reduced water volume and less spawning success than recirculating system. Access to this reach from downstream reaches 2 or 3 would also be limited due to reduced flows, shallow water depth, and development of dense stands of aquatic vegetation within these lower reaches.
Endangered species (wood stork)	No utilization - lack of suitable habitat.	No utilization - lack of suitable habitat.	No utilization - lack of suitable habitat.	No utilization - lack of suitable habitat.
Waterfowl	No utilization - lack of suitable habitat.	Very low utilization - lack of suitable habitat.	Very low utilization - lack of suitable habitat.	Very low utilization - lack of suitable habitat.

a. Reach 1 comprises approximately 1 percent of the Pen Branch system that is influenced by reactor operation.

b. Stream system expected within a 15-year period after reactor operations cease.

BB-3

Table 4-29. Comparison of Potential Environmental Impacts in Reach 2^a of Pen Branch System
(page 1 of 2)

Parameter	Alternative cooling water system			
	No action	Once-through cooling tower	Recirculating cooling towers	Natural stream ^b
Flow (variation), m ³ /sec	11.5 (1.17-11.5)	10.7 (1.17-10.7)	1.17 (0.2-1.17)	0.17 (natural)
Temperature (°C), Maximum/ ΔT	63/30	32/6	29/3	26/0
Vegetation				
Aquatic	Thermally tolerant algae only.	Limited macrophyte development due to high flows; more available habitat than in Reach 1.	Increased macrophyte development over once-through system, but less available habitat due to reduced flows.	Less available habitat due to reduced flow volume, greater diversity than once-through system.
Riparian	Isolated communities limited to sandbars and stumps due to high flows and temperatures.	Isolated communities limited to sandbars and stumps due to high flow.	Major increase in available habitats; shrub/herb community development; greater species diversity due to reduced flows.	Highest species diversity; invasion by some nonwetland species.
Macroinvertebrates	Minimal use by thermally tolerant species (e.g., oligochaetes and nematodes).	Greater abundance and diversity than in Reach 1; moderate potential for early emergence due to ΔT ; stranding possible due to variable flow rates from reactor operations.	Moderate improvement in available habitat over those in Reach 1 due to downstream reductions in flow and temperature. Some potential for early emergence. Little chance of stranding due to more stable flows.	Least amount of available habitat due to reduced water volume; highest species density; no potential for early emergence or stranding.

BB-3

Table 4-29. Comparison of Potential Environmental Impacts in Reach 2^a of Pen Branch System
(page 2 of 2)

Parameter	No action	Alternative cooling water systems		
		Once-through cooling tower	Recirculating cooling towers	Natural stream ^b
Fish	Limited habitat improvement over Reach 1; brief utilization by fish during reactor shutdowns; no spawning during reactor operations; some spawning could occur during long shutdowns.	Moderate improvement in habitat conditions (i.e., reduced temperatures and flows) compared to Reach 1; presence of flow-tolerant species; increased spawning; limited utilization by anadromous species.	Moderate improvement in habitat conditions over those in Reach 1 and once-through systems due to reduced temperatures and flows in upper reach. Reduced utilization and spawning near delta due to reduced flows in shallow depths and development of dense vegetation, which would limit potential access by anadromous and/or riverine species to upper part of Reach 2 and to Reach 1.	Less available habitat and spawning success than recirculating system, limiting access by anadromous and/or riverine species to upper reaches due to reduced flows and dense vegetation.
Endangered species (wood stork)	No utilization due to excessive temperatures and flow.	No utilization due to flows and excessive water depth.	Very low utilization.	Very low utilization due to reduced flows and dense vegetation.
Waterfowl	No utilization.	Moderate utilization in backwater areas.	Moderate utilization.	Moderate utilization.

a. Reach 2 comprises approximately 10 percent of the Pen Branch system that is influenced by reactor operations.

b. Stream system expected within a 15-year period after reactor operations cease.

BB-3

Table 4-30. Comparison of Potential Environmental Impacts in Reach 3^a of Pen Branch System
(page 1 of 2)

Parameter	Alternative cooling water system			
	No action	Once-through cooling tower	Recirculating cooling towers	Natural stream ^b
Flow (variation), m ³ /sec	Highly variable; strongly influenced by Savannah River flows below delta.	Highly variable; strongly influenced by Savannah River flows below delta.	Highly variable; strongly influenced by Savannah River flows below delta.	Highly variable; strongly influenced by Savannah River flows below delta.
Temperature (°C) Maximum/ Δ T	51/14	31/1	29/0	30/0
Vegetation				
Aquatic	Thermally tolerant algae and bacteria only.	Submerged macrophytes limited to edge of delta and lower braided stream area; extensive where present.	Less available habitat than with once-through system; greater abundance due to reduced flow and stable water depth.	Less available habitat than with recirculating system; dense concentrations.
Riparian	Delta - Thermally tolerant herbaceous flora.	Delta - Herbaceous marsh present; should extend into the cypress/tupelo die-off area.	Delta - Herbaceous marsh present but less extensive than once-through system; some shrub species present; old-field species would occur in drier areas.	Delta - Greater development of old-field community; less marsh and shrub vegetation than recirculating system; development of nonwetland species.
	Swamp - Cypress/tupelo community.	Swamp - Cypress/tupelo community.	Swamp - Cypress/tupelo community.	Swamp - Cypress/tupelo community.
Macroinvertebrates	Greater community diversity than in Reach 2; dominated by thermally tolerant species (e.g., oligochaetes and nematodes).	Great increase in diversity and abundance over no action due to temperature reduction; stranding due to variable flows limited to delta area (swamp	Less available habitat but higher quality than with once-through system due to reduced flows; great increase in diversity and abundance over no action; little chance	Less available habitat than recirculating system; similar in abundance and diversity; little chance of stranding due to more stable flows.

BB-3

Table 4-30. Comparison of Potential Environmental Impacts in Reach 3^a of Pen Branch System
(page 2 of 2)

Parameter	Alternative cooling water system			
	No action	Once-through cooling tower	Recirculating cooling towers	Natural stream ^b
Fish	Only thermally tolerant species near delta; brief utilization by fish during reactor shutdowns; limited utilization and spawning by anadromous species in upper swamp due to high temperatures.	flow is regulated by Savannah River); no early emergence expected. Habitat greatly improved over Reach 2; increased spawning success, utilization, and access by anadromous and riverine species due to reduced temperatures.	of stranding due to more stable flows. Reduced utilization and spawning in delta area due to reduced flows, shallow water depth, and development of dense vegetation, which would limit potential access to upper reaches. Habitat for spawning and nursery areas in swamp depends on periodic flooding by Savannah River.	Less available habitat and spawning success than recirculating system due to reduced flow and extensive vegetation in delta area. Swamp utilization similar to that for recirculating system.
Endangered species (wood stork)	Very low utilization due to excessive temperatures and flow.	Very low utilization in delta area due to flows.	Increased utilization for feeding due to reduced flows in delta area; this would decrease as vegetation invades.	Limited utilization due to reduced flows in delta area. Decreased use due to vegetation invasion, which would be more rapid than for recirculating system.
Waterfowl	High to moderate utilization, particularly below the delta.	High to moderate utilization of all alternatives due to reduced temperatures near delta.	Moderate utilization; less than with once-through system due to less available habitat from flow reduction near delta and extensive vegetation.	Moderate to low utilization due to less available habitat and less use than with once-through system due to extensive vegetation.

a. Reach 3 comprises approximately 89 percent of the Pen Branch system, as utilized for the HEP analysis (Mackey et al., 1987).

b. Stream system expected within a 15-year period after reactor operations cease.

With the once-through cooling-tower alternative, communities of aquatic and riparian vegetation should develop, but the areal extent, abundance, and species diversity would be limited due to the presence of high and variable cooling water flows. The early emergence of some macroinvertebrate species could occur because of the elevated water temperature; stranding of some macroinvertebrate communities could occur as a result of reactor-induced variations in flow. The fishery community would be limited in size and dominated by species with high flow tolerance (i.e., minnows, suckers, and darters). Spawning by fish would be extremely limited due to fast flow, high stream gradient, and channelized banks. The utilization of Reach 1 by anadromous and riverine species would be limited due to its distance (6 to 8 kilometers) from the Savannah River.

With the recirculating cooling-tower alternative, an increase in the areal extent and diversity of riparian vegetation would occur in comparison with those for the once-through system. An increase in the areal extent of aquatic macrophytes also would occur, but, because of the reduced water flows to be experienced with this alternative, the total available habitat would be reduced. Less habitat would be available for macroinvertebrate communities, but the abundance per unit area would be comparable to that for the once-through system. Species diversity would be greater and the potential for early emergence of macroinvertebrate species would be reduced over that for the once-through system because of reduced temperatures. The more stable water flows would produce little chance of stranding of macroinvertebrates. The reduced flow associated with this system would limit the areal extent of available habitat for fish; however, this habitat would be of higher quality than that for any of the alternatives. This alternative would provide the highest potential standing crop of fish of the alternatives; higher spawning per unit area should occur than with the once-through system. However, access to this region by anadromous or riverine fish species from Reaches 2 and 3 is unlikely due to reduced flows, shallow water depth, and development of dense stands of aquatic vegetation.

BB-3

The complete cessation of reactor operations (i.e., a return to natural stream conditions) would provide less available habitat for aquatic vegetation and macroinvertebrates than the recirculating cooling-tower alternative due to a further reduction in water flows. Riparian areas would be colonized by some nonwetland vegetation. However, the species diversity of these communities would be the highest of all identified alternatives. No potential would exist for the early emergence of any macroinvertebrate species. Less habitat would be available for fish, and spawning success would be less than that for the recirculating system due to lower flows. In addition, access to this region by fish from downstream Reaches 2 and 3 would be unlikely due to reduced flows, shallow water depths, and the expected development of dense stands of aquatic vegetation.

The stream gradient and flows of Reach 1 would not provide suitable habitat for the endangered wood stork or for waterfowl with any alternative.

Impacts On Reach 2

Reach 2 extends from SRP Road A to the Pen Branch delta. This reach encompasses approximately 10 percent (110 of 1100 acres) of the Pen Branch system that is influenced by reactor cooling water discharges, as utilized for

The high flows and temperatures expected in Reach 2 (Table 4-29) with the selection of the no-action alternative would allow the occurrence only of isolated communities of riparian vegetation (limited to sandbars and stumps); aquatic vegetation would be limited to thermally tolerant algae. Thermally tolerant macroinvertebrate species would make minimal use of the reach. Only limited improvement in the quality of fish habitat would be expected over the conditions described for Reach 1. Utilization by fish would be limited to brief reactor shutdown periods. No spawning would occur during reactor operations; however, limited spawning could occur during long shutdowns. The high flows and temperatures would preclude the use of this reach by the endangered wood stork and waterfowl.

BB-3 The once-through cooling-tower alternative would reduce water temperatures below those for no action, but flows would remain high and variable (Table 4-29). The high flows would limit riparian vegetation to isolated communities on sandbars and stumps. Limited macrophyte development would occur in backwater areas of reduced flow; more total habitat would be available than in Reach 1. The macroinvertebrate community would have greater species diversity and abundance in comparison to Reach 1. Only minimal early emergence should occur with some macroinvertebrate species due to elevated temperature; some stranding of portions of the macroinvertebrate community could occur due to reactor-influenced flow variations. A moderate improvement in fish habitat conditions over those in Reach 1 would occur due to downstream reductions in temperature, gradient, depth, and flows; this should provide the greatest occurrence of flow-tolerant species and more moderate spawning activity within the reach. Use of this reach by anadromous species would be limited. The endangered wood stork would not use Reach 2, but limited habitat would probably be available for waterfowl in backwater areas.

With the recirculating cooling-tower alternative, reduced flow and temperature would provide an increase in riparian habitat (i.e., development of a shrub/herb community) and greater species diversity in Reach 2. Reduced flows would also enable greater aquatic macrophyte development to occur in comparison to the once-through alternative; however, less total habitat area would be available. A moderate improvement would occur in habitat available for the macroinvertebrate community, in comparison to that expected in Reach 1 with this alternative and to the once-through alternative, as a result of reductions in temperature and flow. Early emergence of macroinvertebrate species would not occur. The reduced flows and temperatures would also provide moderate improvement of fish habitat in the upper portions of Reach 2; however, the reduced water flows and the increased development of vegetation in the lower portions of the reach probably would cause reduced use and spawning in the shallow areas of the delta. Access by fish to the upper portion of Reach 2 and to Reach 1 could become limited due to reduced flows and dense vegetation development. Limited use of this reach by the endangered wood stork and waterfowl would occur.

With a complete cessation of reactor cooling water flows (natural stream conditions), the reduced water volumes in the stream would cause further reductions in available habitat for aquatic vegetation, macroinvertebrates, and fish in comparison to the recirculating cooling-tower alternative (Table 4-29). However, species diversity of the aquatic and riparian vegetation and macroinvertebrate communities would be greater in areas where habitat is

and fish in comparison to the recirculating cooling-tower alternative (Table 4-29). However, species diversity of the aquatic and riparian vegetation and macroinvertebrate communities would be greater in areas where habitat is available. There would be no potential for early emergence of any macroinvertebrate species, and reactor-influenced stranding would not occur. The reduced water volumes would cause the present riparian habitat to be colonized by nonwetland species. The reduced flows and increased density of vegetation would limit fish access to the upper reaches of the stream and, thus, limit overall use and spawning. The endangered wood stork would not use Reach 2, but limited use by waterfowl would occur.

Impacts On Reach 3

Reach 3 of the Pen Branch system, as utilized for the HEP analysis (Mackey et al., 1987) extends from the Pen Branch delta approximately 2 kilometers into the Savannah River swamp; it encompasses approximately 89 percent (988 of 1100 acres) of the Pen Branch system. However, approximately 40 percent of this reach is considered to be part of the Savannah River swamp and, therefore, is not influenced by reactor operations (Mackey et al., 1987). The stream in Reach 3 is highly braided; the gradient is the lowest of all the reaches; sheet flow is prevalent; and water flows are extremely variable, influenced primarily by periodic Savannah River flooding. The following discussions for each alternative consider only the portion of Reach 3 that potentially is influenced by reactor operations.

With the no-action alternative, aquatic vegetation would be limited to thermally tolerant algae and bacteria (Table 4-30). Riparian vegetation in the delta probably would consist of thermally tolerant herbaceous flora; in the swamp, the cypress-tupelo community would predominate. The macroinvertebrate community would be more diverse than that in Reach 2, but it would be dominated by thermally tolerant species (e.g., Oligochaetes and Nematodes). Only thermally tolerant fish species would occur in the delta area. Brief use by some species would occur during reactor shutdowns. In the swamp, high temperatures would limit use and spawning by anadromous species. The endangered wood stork would not use Reach 3 with this alternative; however, extensive use by waterfowl should occur, particularly below the delta.

BB-3

With the once-through cooling-tower alternative, submerged macrophytes should develop, but their distribution would be limited to the edge of the delta and the lower sections of the braided-stream area; in this area, high abundance would occur. Herbaceous marsh should develop in the riparian areas of the delta, while the cypress-tupelo community would predominate in the swamp. As a result of the large reduction in water temperatures, a substantial increase in macroinvertebrate community diversity and abundance would occur in comparison to the no-action alternative. No early emergence of any species should occur, and stranding due to variable flows would be limited to the delta area because flow in the swamp is influenced strongly by Savannah River flows. Because of lower flows and temperatures, fish habitat should be greatly improved over that present upstream; much greater use and spawning success would occur. Some access to Reach 2 would be available for anadromous and other species. Because of high flows, the endangered wood stork probably would not use this reach for foraging; however, because of lower water temperatures, waterfowl should use the delta area to a greater extent than they would for the no-action alternative.

BB-3

Less aquatic vegetation habitat would be available with the recirculating cooling-tower system than with the once-through alternative (Table 4-30). However, the reduction in flow and the resultant decrease in water depths would provide greater vegetation abundance in the areas of occurrence. In the delta area, herbaceous marsh should occur but in less abundance than with the once-through alternative; shrub species would also be present and old-field species would occur in the drier areas. In the swamp, the cypress-tupelo community would predominate. Less macroinvertebrate habitat would be available than with the once-through system, but the habitat would be of higher quality because of reduced, stable flows. A substantial increase in macroinvertebrate community diversity and abundance would occur, and there would be little chance of stranding due to the more stable flows. Fish use and spawning would be reduced in the delta area as a result of the reduced flow, shallow water depths, and increased densities of vegetation, all of which could also limit access to the upper stream reaches. In the swamp, a high-quality habitat for spawning and nursery functions would occur as a result of the influence of the Savannah River on water levels. Use of the delta area by the endangered wood stork would increase as a result of reduced flows; however, this eventually would decrease as revegetation of the area proceeds. Less habitat would be available in the delta for waterfowl in comparison to the once-through alternative because of flow reduction and the related revegetation of the area.

With a complete cessation of reactor cooling water discharge (natural stream conditions), less habitat would be available for aquatic vegetation than with the recirculating cooling-tower alternative. However, in the available areas, dense concentrations should occur. In the riparian areas of the delta, there would be greater development of an old-field community, with less marsh and shrub vegetation than with the recirculating alternative. In the swamp, the cypress-tupelo community would predominate. Less macroinvertebrate habitat would be available, but community diversity and abundance should be similar to those for the recirculating alternative. There should be little chance of macroinvertebrate stranding due to more stable flows. In the delta area, less fish habitat would be available and spawning success should be less because of reduced flow and revegetation effects that reduce aquatic habitat. However, in the swamp, fish use should be similar to that with the recirculating system. Limited use of the delta area by the endangered wood stork should occur; this would decrease at a more rapid rate than with the recirculating alternative due to revegetation. There would be less use by waterfowl because revegetation would cause less available habitat.

AD-1
BC-6

The present worth cost of the once-through cooling-tower system for both reactors would be approximately \$93 million less than that for recirculating cooling towers. However, recirculating cooling towers would cost approximately \$4 million less to operate each year. In addition, recirculating cooling towers would require approximately 6 months longer to construct. The implementation of recirculating cooling towers could reduce reactor power by 3.7 percent, compared to only 0.2 percent with the once-through system (both systems were compared to the No-Action alternative). Costs to conduct a Section 316(a) Demonstration study would be the same for either alternative, about \$1.25 million.

TC

4.6.1.1 Once-Through Cooling Tower

The estimated present worth for the once-through natural-draft cooling tower with gravity feed at K-Reactor would be approximately \$43 million, including production losses (\$41.4 million without production losses). Estimated annual operating costs would be \$6.4 million. Preliminary design studies suggest a 0.2-percent annual average loss of reactor power attributable to the operation of a once-through tower system in comparison to the No-Action alternative. Construction would require about 36 months, after a 9-month lead design period.

AD-1
BC-6

The implementation of this alternative would reduce the thermal effects in Pen Branch and its delta, while maintaining the current flow levels, thereby increasing the available aquatic habitat for fishes and other organisms. Continued wetland losses would decrease, and some successional revegetation would occur. Entrainment and impingement losses would be about the same as with current operations. Fluctuating water levels and flow rate could inundate the eggs, nests, and hibernation sites of the American alligator. The availability of foraging habitat for the wood stork would be limited due to water depth and flow. Air quality impacts, including fogging and icing, elevated visible plumes, and total-solids (drift) deposition would be insignificant.

BC-10
BC-14

About 50 additional curies of tritium would be released per year to the atmospheric pathway and about 50 curies less per year to the liquid pathway for this alternative. This would result in a reduction of the maximum individual effective whole-body dose of 1.1×10^{-4} millirem per year. The total collective effective whole-body dose would decrease by 2.8×10^{-2} person-rem per year. These dose changes are very small in comparison to existing operations and natural background. The dose to onsite construction personnel due to slightly elevated background levels of radiation produced by plant facilities would be 20 millirem per year, based on 2000 hours for cooling-tower construction.

TE

The major environmental benefit of this alternative compared to the recirculating cooling tower would be that current flow rates in the creek and delta would be maintained, thereby providing more potential habitat for spawning and foraging by fishes. The present-worth value of this alternative would be \$47 million less than that for recirculating towers.

TC

The principal environmental benefit of this alternatives over the no-action alternative would be the reduction of thermal effects in Indian Grave Branch and Pen Branch and the delta and an associated increase in dissolved oxygen levels.

TE

4.6.1.2 Recirculating Cooling Towers

The estimated present worth of this alternative would be approximately \$90 million including production losses (\$58 million without production losses). Estimated annual operating costs would be \$4.4 million. Preliminary design criteria suggest a 3.7-percent annual average loss of reactor power attributable to the operation of a recirculating cooling-tower system, in comparison to the no-action alternative. Construction would require about 42 months, after a 9-month lead design time.

AD-1
BC-6

BC-1
BC-19
BD-5

BB-3
This alternative would reduce water temperatures in Pen Branch and its delta, but would also greatly reduce the flows in these areas. Approximately 0.6 cubic meters per second would be discharged as a result of this alternative, in contrast to the present discharge rate of 10.5 cubic meters per second. The reduction in thermal effects would allow recolonization by fishes and other organisms but would greatly reduce the habitat area. Losses of wetlands would essentially cease, and an estimated 500 acres should become re-established through the process of natural plant succession. There should be no impacts associated with cold shock during the winter. Total annual entrainment (eggs and larvae) would be reduced from 13.4×10^6 to 2.0×10^6 , while total annual impingement would be reduced from approximately 2942 to 427 fish. Habitat quality for the American alligator would be improved; the inundation of eggs, nests, and hibernation sites would be improbable. The availability of foraging habitat for the endangered wood stork would be enhanced.

Impacts to air quality would be similar to those expected for a once-through tower and, although salt deposition would be higher than that for the once-through tower, levels would be far below those that would cause vegetative stress.

BB-3
The operation of this alternative would reduce flows in Pen Branch, resulting in a decrease in the cesium-137 release to the Savannah River of 0.12 curie per year. About 425 additional curies of tritium would be released per year to the atmospheric pathway, and 425 fewer curies of tritium would be released per year to the liquid pathway. The reduction in cesium-137 and the change in the release of tritium would result in a decrease in the maximum individual effective whole-body dose of about 7.0×10^{-2} millirem per year. The collective effective whole-body dose would decrease by about 4.8×10^{-1} person-rem per year. The dose to onsite construction personnel due to slightly elevated background levels of radiation produced by SRP facilities would be 20 millirem per year, based on 2000 hours for cooling-tower construction.

The principal environmental benefits of recirculating cooling towers compared to the once-through cooling-tower system would be the reestablishment of a greater amount of wetlands and the reduction in entrainment and impingement losses.

The major advantage over the no-action alternative would be the improvement in water quality in Pen Branch and its delta by the reduction of temperatures and flows and the increase in dissolved oxygen concentrations.

4.6.1.3 No Action

There would be no capital costs or increases in annual operating costs with this alternative.

BB-4
The no-action alternative would result in the continuation of thermal discharge effects to Pen Branch and its delta. The high-water temperatures would prevent fish from using the waterways for foraging or spawning and would not meet State of South Carolina Class B water classification standards. A potential for cold shock would remain and annual wetland losses of about 26 acres per year would continue. Entrainment and impingement losses would be

maintained at current levels. Habitat value for the American alligator, which has been classified as "threatened due to similarity of appearance," and endangered wood stork would remain low. There would be no impacts on air quality, noise, or archaeological sites with this alternative.

BB-4

The maximum individual dose would continue at about 3.3 millirem per year. The collective dose would be about 80.7 person-rem per year and is about 0.074 percent of natural background.

There are no important environmental benefits to the no-action alternative with respect to either the once-through or recirculating cooling towers. There would be a considerable savings in construction (a minimum of \$41.4 million) and operating (a minimum of \$4.4 million per year) costs over those for the implementation of either cooling-tower system.

AD-1
BC-6

4.6.2 ALTERNATIVES FOR C-REACTOR

The comparison of impacts of the two cooling-tower alternatives for C-Reactor are similar to those associated with K-Reactor described in Section 4.6.1.

TC

4.6.2.1 Once-Through Cooling Tower

The estimated present worth for the once-through, natural-draft, gravity-feed cooling tower at C-Reactor would be approximately \$44 million, including production losses (\$42.4 million without production losses). The estimated annual operating costs would be \$6.4 million. The construction would require 36 months following a 9-month design phase. Reactor power should drop by 1 percent due to the operation of the once-through system, compared to the No-Action alternative. As with K-Reactor, C-Reactor would require an additional \$1.25 million for a 316(a) Demonstration study.

AD-1
BC-6

The implementation of this alternative would reduce the thermal effects in Four Mile Creek and its delta while maintaining the current flow levels, thereby increasing the available aquatic habitat for fishes and other organisms. Continued wetland losses would decrease, and some successional revegetation would occur. Entrainment and impingement losses would be about the same as with current operations. Fluctuating water levels and flow rate could inundate the eggs, nests, and hibernation sites of the American alligator. The availability of foraging habitat for the wood stork would be limited due to water depth and flow. Air quality impacts, including fogging and icing, elevated visible plumes, and total-solids (drift) deposition would be insignificant. The construction of the once-through cooling tower would disturb one known prehistoric site that has been determined to be insignificant.

BB-3

About 50 additional curies of tritium would be released per year to the atmospheric pathway, and about 50 curies less would be released per year to the liquid pathway for this alternative. This would result in a reduction of the maximum individual effective whole-body dose of 1.1×10^{-4} millirem per year. The total collective effective whole-body dose would decrease by 2.8×10^{-2} person-rem per year. These dose changes are very small in comparison to existing operations and natural background. The dose to onsite construction personnel, due to slightly elevated background levels of radiation

produced by plant facilities, would be 20 millirem per year based on 2000 hours for cooling-tower construction.

BC-6 | An advantage of the once-through tower over recirculating towers would be the maintenance of existing flow levels in the creek and delta, thereby providing more potential habitat for fish and other organisms. The present-worth value of this alternative would be approximately \$46 million less than that for recirculating towers.

The principal advantage of a once-through tower over no action would be the reduction of water temperatures and an increase in concentrations of dissolved oxygen in Four Mile Creek.

4.6.2.2 Recirculating Cooling Towers

BC-6 | The estimated present worth of this alternative would be approximately \$90 million including production losses (\$58 million without production losses). Estimated annual operating costs are \$4.4 million. In addition to these costs, the estimated cost to conduct a Section 316(a) Demonstration study would be \$1.25 million. Preliminary design criteria suggest a 4-percent annual average loss of reactor power attributable to the operation of a recirculating cooling-tower system, compared to the no-action alternative. Construction would require about 42 months, after a 9-month lead design time.

BB-3
BD-5 | This alternative would reduce water temperatures in Four Mile Creek and its delta, but would also reduce the flow in these areas by about 92 percent. The reduction in thermal effects would allow recolonization by fishes and other organisms but would greatly reduce the habitat area. Losses of wetlands would essentially cease, and an estimated 1000 acres would become reestablished through the process of natural plant succession. There would be no impacts associated with cold shock during the winter. Total annual entrainment (eggs and larvae) would be reduced from 13.4×10^6 to 2.0×10^6 , while total annual impingement would be reduced from approximately 2942 to 427 fish. Habitat quality for the American alligator would be improved; the inundation of eggs, nests, and hibernation sites is unlikely. The availability of foraging habitat for the endangered wood stork would be enhanced. Impacts to air quality would be similar to those expected for a once-through tower and, although salt deposition would be higher than for once-through towers, levels would be far below those that cause reduced vegetative productivity. The same prehistoric site that would be disturbed by construction of the once-through system would be impacted by this alternative.

BC-22 | This alternative would result in a decrease of 0.21 curie per year of cesium-137 released to the Savannah River. The radiological releases for C-Reactor would be similar to those described for K-Reactor in Section 4.6.1.2, except the total decrease in the maximum individual effective whole-body dose and the collective effective whole-body dose due to cesium and tritium releases would be 1.2×10^{-1} millirem per year and 6.6×10^{-1} person-rem per year, respectively. The dose to onsite construction personnel due to slightly elevated background levels of radiation produced by SRP facilities would be 20 millirem per year, based on 2000 hours for cooling-tower construction.

The principal environmental benefits of this system over a once-through tower would be the successional re-establishment of a greater amount of wetlands and the reduction of losses due to entrainment and impingement.

4.6.2.3 No Action

The no-action alternative would result in no changes in the existing impacts on the aquatic and wetland environments associated with the Four Mile Creek system. These impacts would be similar to those described for Pen Branch and its delta (see Section 4.6.1.3).

This alternative would not comply with South Carolina's Class B water classification standards. Radiological releases would be approximately the same as those described in Section 4.6.1.3 for K-Reactor, except cesium-137 releases from creek sediments would be slightly lower. There would be a considerable construction cost savings (more than \$90 million) over the other two systems.

4.6.3 COMPARISONS FOR D-AREA

4.6.3.1 Increased Flow with Mixing

Increased flow could be implemented immediately without any capital costs. Annual operating costs would increase by about \$30,000 per year.

The implementation of this alternative would reduce the thermal effect in Beaver Dam Creek during extreme summer temperatures by temporarily increasing flow. The lowering of water temperatures would improve the aquatic habitat in the creek, which would permit greater use by aquatic organisms. Entrainment and impingement losses would remain about the same as with current operations, because there are few adults and spawning in the vicinity of the intake during the summer. Temporary wetland losses would only total about 4 acres during periods when pumping was necessary. American alligator habitat would not be affected, but some decrease of wood stork habitat in the area could result from greater water depths during periods when extra pumping would be required to meet Class B water classification standards. There would be no impacts to air quality, noise, release of radionuclides, or archaeological resources due to the implementation of this alternative.

The principal advantage of this alternative over direct discharge would be that present flows in Beaver Dam Creek would be maintained, thereby preserving the existing aquatic habitat and habitat for the American alligator (threatened due to "similarity of appearance") and endangered wood stork. In addition, the estimated costs of implementing this alternative would be about \$14 million less than those for the direct-discharge alternative.

BB-5

The advantage of this alternative over no action would be the reduction of thermal effects in the creek during periods of high summer temperatures.

4.6.3.2 Direct Discharge

Construction of the discharge pipeline would require a capital cost of approximately \$14 million and about 22 months to complete. Its operation would increase annual operating costs by about \$50,000 per year.

This alternative would lower water temperatures to ambient levels in Beaver Dam Creek by discharging the powerhouse effluent directly to the Savannah River. The removal of the discharge flow from Beaver Dam Creek would decrease water levels in the creek, thereby reducing available spawning and foraging habitat for aquatic organisms. An estimated 1 acre of wetlands and 5 acres of uplands also would be affected by the construction of the pipeline. There would be small increases in water temperatures within the discharge mixing zone in the river. Entrainment and impingement effects would be the same as for present operating conditions. The decrease in water level and removal of heated water from the creek would significantly degrade the existing endangered American alligator and wood stork habitat. There would be no impacts on air quality, noise, radiological releases, or archaeological resources.

The only advantage of direct discharge over the increased flow alternative would be the complete elimination of all thermal discharges from Beaver Dam Creek. The advantage of this alternative over no action would be the elimination of releases of heated water to the creek.

4.6.3.3 No Action

TC | This alternative would require no costs or delays. It would maintain the existing environmental conditions in Beaver Dam Creek. Periodically, water temperatures would exceed the 32.2°C Class B water classification standards and would continue to limit the use of the area by aquatic organisms at these times. Entrainment and impingement losses would remain at present levels. The existing habitat for the American alligators ("threatened due to similarity of appearance") and marginal foraging habitat for the endangered wood stork would be unchanged.

An environmental advantage to selecting the no-action alternative over increased flow would be the prevention of adverse impacts to about 4 acres of wetlands and 4 acres of uplands; there would also be a saving in estimated operating costs.

TC | The principal environmental benefit of this alternative over direct discharge would be that it would maintain existing water flows and levels in Beaver Dam Creek, thereby maintaining habitat for the American alligator and the wood stork and aquatic organisms. It would also prevent adverse impacts to about 1 acre of wetlands and 5 acres of uplands due to construction. There would also be a capital cost savings of \$14 million initially and \$140,000 per year thereafter.

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CHAPTER 5

FEDERAL AND STATE ENVIRONMENTAL REQUIREMENTS

This chapter summarizes the major Federal and State of South Carolina requirements that are applicable to the cooling water alternatives for K- and C-Reactors and the D-Area coal-fired powerhouse. Section 5.1 discusses applicable statutes and regulations. Sections 5.2 through 5.8 identify the actions that have been taken to satisfy these requirements. Table 5-1 lists the permits and other environmental approvals needed to implement the cooling water alternatives and the status of each.

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In addition to securing these permits and complying with applicable standards, the U.S. Department of Energy (DOE) is required to comply with several separate environmental requirements, such as the National Environmental Policy Act (NEPA) and floodplain/wetlands review. DOE has established its own orders and regulations to ensure the environmental, health, and safety protection of its facilities (Section 5.9).

5.1 APPLICABLE STATUTES AND REGULATIONS

National Environmental Policy Act of 1969, as amended (NEPA) (42 U.S.C. 4321 et seq.)

The National Environmental Policy Act of 1969, as amended, requires "all agencies of the Federal Government" to prepare a detailed statement on the environmental effects of proposed "major Federal actions significantly affecting the quality of the human environment." This environmental impact statement has been prepared in accordance with the Council on Environmental Quality Regulations on Implementing the National Environmental Policy Act (40 CFR 1500-1508) and DOE Guidelines for Compliance with the National Environmental Policy Act (45 FR 20694, March 28, 1980), as amended.

Atomic Energy Act of 1954, as amended (42 U.S.C. 2011 et seq.)

DOE is required to comply with radiation guidance established pursuant to the Atomic Energy Act of 1954, as amended [42 U.S.C. 2201(g)], which authorizes the establishment by rule, regulation, or order standards to protect health or minimize dangers to life or property. In accordance with the Energy Reorganization Act of 1974, DOE defense-related operations are not subject to the regulations of the Nuclear Regulatory Commission. DOE has issued extensive standards and requirements to ensure safe operations.

Executive Order 12088 (October 13, 1978)

This Executive Order requires Federal agencies to comply with applicable administrative and procedural pollution control standards established by, but not limited to, the following Federal laws:

1. Toxic Substances Control Act (15 U.S.C. 2601 et seq.)

Table 5-1. Required Regulatory Permits and Notifications

Activity/facility	Requirement(s)	Agency	Status	
Water				
Cooling water system construction	Construction permits	South Carolina Department of Health and Environmental Control, Industrial and Agricultural Wastewater Division	To be submitted by September 30, 1988, subject to the appropriation of funds by Congress	TC
	Section 404 permit ^a	U.S. Army Corps of Engineers (COE)	To be submitted prior to construction	TC
	Section 401 certification ^b	South Carolina Department of Health and Environmental Control, Division of Water Quality	Requested by COE as part of the dredge and fill permit process	
	Section 10 permit for structures in navigable waters ^a	U.S. Army Corps of Engineers (COE)	To be submitted prior to construction	
	Permit for structures in navigable waters ^a	South Carolina Budget and Control Board	To be submitted prior to construction	
Cooling water discharges	NPDES permit	South Carolina Department of Health and Environmental Control, Industrial and Agricultural Wastewater Division	Issued; modification to permit conditions to be made prior to operation of cooling water system	TE
Compliance with delta 2.8°C temperature requirement ^b	316(a) (thermal impact) study	South Carolina Department of Health and Environmental Control, Industrial and Agricultural Wastewater Division	Plans for conducting studies to be submitted within two months following project completion	
Water withdrawal water use	Quarterly reporting	South Carolina Water Resources Commission	Routine reports will continue to be submitted	

Table 5-1. Required Regulatory Permits and Notifications (continued)

Activity/facility	Requirement(s)	Agency	Status
Endangered species	Consultation/ biological assessment	U.S. Fish and Wildlife Service	Consultations with FWS completed
Fish and Wildlife Coordination Act	Consultation/ consideration of fish and wild- life resources	U.S. Fish and Wildlife Service	Consultations with FWS completed
Migratory Bird Treaty Act	Consultation with FWS	U.S. Fish and Wildlife Service	Consultation with FWS completed
Anadromous Fish Conservation Act	Consultation with FWS	U.S. Fish and Wildlife Service	Consultation with FWS completed
Historic preservation	Archaeological survey and assessment	South Carolina Historic Preservation Officer	Surveys and assess- ments completed; consultation with SHPO completed
Floodplains/wetlands ^c	Assessment and determination	U.S. Department of Energy	Notice published in <u>Federal Register</u> (51 FR 10654) con- currently with Notice of Avail- ability of the draft EIS on March 28, 1986; determination published after completion of FEIS.

a. Applicable to the D-Area coal-fired powerhouse direct discharge alternative.

b. Applicable to once-through cooling-tower alternatives for K- and C-Reactors and the increased pumping alternative for the D-Area coal-fired powerhouse.

c. Refer to Appendix F.

2. Federal Water Pollution Control Act (33 U.S.C. 1251 et seq.)
3. Public Health Service Act, as amended by the Safe Drinking-Water Act [42 U.S.C. 300 (f) et seq.]
4. Clean Air Act (42 U.S.C. 7401 et seq.)
5. Noise Control Act (42 U.S.C. 4901 et seq.)
6. Solid Waste Disposal Act (42 U.S.C. 6901 et seq.), also referred to as the Resource Conservation and Recovery Act

National Historic Preservation Act of 1966 (16 U.S.C. 470 et seq.)

No permits, certifications, or approvals related to historic preservation are required; however, DOE must provide the Advisory Council on Historic Preservation an opportunity for comment and consultation, as required by the Historic Preservation Act of 1966 [16 U.S.C. 470(f) et seq.]. Section 106 of this Act requires any agency with jurisdiction over a Federal "undertaking" to provide the Council an opportunity to comment on the effect the activity might have on properties included in, or eligible for nomination to, the National Register of Historic Places.

In addition, Executive Order 11593 (May 13, 1971) requires Federal agencies to locate, inventory, and nominate properties under their jurisdiction or control to the National Register of Historic Places, if those properties qualify. Until this process is complete, the agency must provide the Advisory Council an opportunity to comment on the possible impacts of the proposed activities on the properties.

Executive Orders 11888 (Floodplain Management) and 11990 (Protection of Wetlands) (May 24, 1977)

These Executive Orders require that government agencies avoid, to the extent practicable, any short- and long-term adverse impacts on floodplains and wetlands wherever there is a practicable alternative. DOE has issued regulations (10 CFR 1022) to establish DOE compliance procedures for these Executive Orders.

Section 118 of the Clean Air Act, as amended (42 U.S.C. 7420)

Section 118 of the Clean Air Act, as amended, requires that each Federal agency, such as DOE, with jurisdiction over any property or facility that might result in air pollutant discharges, comply with "all Federal, State, interstate, and local requirements" with regard to the control and abatement of air pollution. Authority for regulation of air emissions has been delegated by the U.S. Environmental Protection Agency (EPA) to the South Carolina Department of Health and Environmental Control (SCDHEC), Bureau of Air Quality Control. SCDHEC requires air emission construction permits for construction, alteration, or addition to a source of air emissions. Consequently, an air emission operating permit is required for any new and continuing source of air contaminants. A Prevention of Significant Deterioration (PSD) review is required for any proposed new construction or

any modification of a major source that will result in a significant increase in the emission rate. EPA has promulgated final regulations for airborne radiation limits at DOE facilities (40 CFR 61; 50 FR 5190).

Section 316(a) of the Federal Water Pollution Control Act, as amended (33 U.S.C. 1326)

Section 316(a) of the Federal Water Pollution Control Act, as amended, authorizes EPA's Regional Administrator to set alternative effluent limitations on the thermal component of discharges if the owner/operator (DOE) demonstrates that the proposed thermal effluent limitations are "more stringent than necessary to ensure the protection and propagation of a balanced, indigenous population of fish, shellfish, and wildlife in or on a body of water into which the discharge is to be made." This satisfactory demonstration is to be made to SCDHEC, because it has received the NPDES authority and is the decisionmaker; however program overview is by EPA. The owner/operator must demonstrate, for the cooling water alternative to be implemented, that the critical functions of a particular trophic level are maintained in the water body as they existed before the introduction of heat and that the impact caused by the heated effluent will not result in appreciable harm to the balanced, indigenous community. This is to include scientific evidence that a balanced biological community will be maintained; no adverse impacts to threatened and endangered species will occur; no unique or rare habitats will be destroyed; passage zone for representative, important species will be provided; and receiving-water temperatures outside any (State-established) mixing zone will not exceed the upper temperature limits for survival, growth, and reproduction of any representative, important species occurring in the receiving water.

Section 404 of the Federal Water Pollution Control Act, as amended (33 U.S.C. 1344); River and Harbors Act of 1899 (33 U.S.C. 401 et seq.)

The Federal Water Pollution Control Act, as amended, requires all branches of the Federal Government engaged in any activity that might result in a discharge or runoff of pollutants to comply with Federal, State, interstate, and local requirements. The authority to implement these requirements for the discharge of dredged or fill material into the waters of the United States (404 permits) has been given to the U.S. Army Corps of Engineers (COE). SCDHEC has been delegated authority by EPA to regulate wastewater discharges (NPDES permits). Individual (case-by-case) permits issued by COE under Section 404 of the Federal Water Pollution Control Act, as amended, are reviewed by EPA (40 CFR 230). The discharge of dredged and fill material into headwaters of creeks where the natural flow is 0.142 cubic meter per second or less, providing applicable reporting/permitting requirements are met, is covered under a nationwide permit issued by COE.

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The Rivers and Harbors Act of 1899 prohibits dredging, construction, or other work affecting or in navigable waters of the United States, except in compliance with Sections 9 and 10 of the Act. COE is empowered to issue permits specifying acceptable activities in navigable waters (33 CFR 320.4, 321, 322, and 325).

The South Carolina Budget and Control Board has a parallel permitting system with COE (permits for construction in navigable waters, Regulation 19-450),

that is administered by the South Carolina Water Resources Commission (SCWRC). The permit application submitted to COE also serves as the permit application to SCWRC; a separate permit application is not required.

Section 401 of the Federal Water Pollution Control Act, as amended (33 U.S.C. 1341)

Section 401 of the Federal Water Pollution Control Act, as amended, requires certification from SCDHEC so discharges of dredged and fill material into navigable waters will comply with applicable effluent limitations and water-quality standards. This certification is a prerequisite for the 404 permit.

South Carolina Pollution Control Act, as amended (Title 48, Chapter 1 of the 1976 Code of Laws of South Carolina)

Under this Act, SCDHEC has authority to require construction permits for the construction of any wastewater treatment facility and any wastewater collection and transmission system. An engineering report and specifications must be submitted to SCDHEC along with a construction permit application. Construction cannot begin until SCDHEC has approved the engineering report and issued a construction permit.

Noise Control Act of 1972, as amended (42 U.S.C. 4901 et seq.)

Section 4 of the Noise Control Act of 1972, as amended, directs all Federal agencies "to the fullest extent within their authority" to carry out programs within their jurisdictions in a manner that furthers a national policy of promoting an environment free from noise that jeopardizes health or welfare.

Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.)

TC | The Endangered Species Act of 1973, as amended, is intended to prevent the further decline of endangered and threatened species and to bring about the restoration of these species and their habitats. The Act is jointly administered by the Departments of Commerce and the Interior, and does not require a permit, certification, license, or other formal approval. Section 7 does, however, require consultation to determine whether endangered and threatened species are known to be present or to have critical habitats on or in the vicinity of the proposed action.

Fish and Wildlife Coordination Act, as amended (16 U.S.C. 661 et seq.)

The Fish and Wildlife Coordination Act, as amended, requires that equal consideration be given to the conservation of fish and wildlife resources during the development of a water-related project. Specifically, the Act requires that consultation be carried out with FWS and appropriate State wildlife agencies with a view to the conservation of wildlife resources by preventing loss of and damage to such resources and by providing for the development and improvement thereof in connection with the project. DOE is required to give full consideration to the recommendations of the Secretary of the Interior and the State agency. The project plan shall include such justifiable means and measures for wildlife purposes that the reporting agency finds should be

adopted to obtain maximum overall project benefits. No permit is required by this Act. However, DOE, subsequent to its consultations with FWS, will consider the mitigation of impacts to fish and wildlife resources in accordance with the FWS Mitigation Policy (DOI, 1981).

Migratory Bird Treaty Act (16 U.S.C. 703 et seq.)

The Migratory Bird Treaty Act was enacted primarily to protect birds that have common migration patterns between the United States and Canada, Mexico, Japan, and Russia. It regulates the harvest of migratory birds by specifying the mode of harvest, hunting seasons, and bag limits. The Act stipulates that it is unlawful at any time, by any means, or in any manner to "kill...any migratory bird." Thus, avian mortality attributable to SRP operations would be unlawful under the provisions of this Act. Although no permit for this project is required under the Act, DOE is required to consult with FWS regarding impacts to migratory birds, and to evaluate ways to avoid or minimize these effects in accordance with the FWS Mitigation Policy (DOI, 1981).

Anadromous Fish Conservation Act (16 U.S.C. 757a-f)

The principal purpose of the Anadromous Fish Conservation Act is to enhance the conservation and development of the anadromous fishery resources of the United States that are subject to depletion from water resource development. Its applicability to the Plant is that populations of anadromous fishes are to be sustained and their movements unobstructed by Plant operations. Although there is no permit required by this Act, DOE is required to consult with FWS regarding impacts to anadromous fishes, and to evaluate ways to avoid or minimize these effects in accordance with the FWS Mitigation Policy (DOI, 1981). When an anadromous fish is an endangered species, the National Marine Fisheries Service (U.S. Department of Commerce) would be involved through the Endangered Species Act.

Safe Drinking Water Act, as amended (42 U.S.C. 300f et seq.)

The Safe Drinking Water Act's primary objective is to protect the quality of public water supplies and all sources of drinking water. SCDHEC has primary enforcement responsibility through the State Safe Drinking Water Act of 1976, as amended (Title 44, Chapter 55 of the 1976 Code of Laws of South Carolina). SCDHEC administration and enforcement consist of construction permits, preliminary site inspections, final construction inspections, monthly sampling collections, and regular operations and maintenance inspections.

5.2 HISTORIC PRESERVATION

An archaeological survey and testing program was conducted by the Savannah River Plant Archaeological Research Program, South Carolina Institute of Archaeology and Anthropology, from May 16 through August 17, 1984, to determine the significant sites that would be affected by the implementation of cooling water alternatives for K- and C-Reactors in the Pen Branch and Four Mile Creek areas. During this survey, 65 discrete archaeological resource sites were located and 23 were considered to be significant. The only site that potentially could be affected by proposed alternatives for C-Reactor is

38BR548; however, it is one of the 42 sites considered to be not significant. The proposed cooling water alternatives for K-Reactor involve none of the sites.

The 23 sites that are considered to be archaeologically significant are potentially eligible for nomination to the National Register of Historic Places. Consultation with the South Carolina State Historic Preservation Officer (SHPO) has resulted in the opinion that the construction of alternative cooling water systems for K- and C-Reactors will have "no adverse effect" on sites eligible for inclusion in the National Register. DOE, as part of its regular monitoring program of the onsite streams, will monitor flows in Beaver Dam Creek, Four Mile Creek, and Pen Branch. If any erosion that would impact any archaeological site is found, DOE will notify the SHPO, as was requested when the no adverse impact determination was rendered (Lee, 1986).

An extensive archaeological survey was conducted by the SRP Archaeological Research Program during October and November 1985 along Beaver Dam Creek to identify significant archaeological sites that could be affected by the cooling water alternatives for the D-Area powerhouse. During this survey, no significant archaeological sites were located that would be affected by the direct-discharge alternative. One significant site was identified that fell within the general area potentially affected by the increased-flow-with-mixing alternative. However, because of its specific location, this site would not be affected by erosion or inundation from increased pumping to the raw-water basin alternative. This site has been recommended by DOE to the State Historic Preservation Officer for eligibility for nomination to the National Register of Historic Places. Neither the Advisory Council on Historic Preservation (Klima, 1986) nor the State of South Carolina Historic Preservation Officer (Lee, 1986) object to a determination of "no effect" for archaeological site 38BR450 in relation to increased flows in Beaver Dam Creek (D-Area).

5.3 SOLID WASTE DISPOSAL

The SRP Sanitary Landfill is designed and operated according to SCDHEC guidelines for receiving domestic waste from SRP construction and operational activities. The Sanitary Landfill site is being expanded to 67 acres. Solid nonhazardous wastes generated during construction of selected alternatives will be disposed of in this facility. No hazardous wastes will be generated as a result of implementing any cooling water alternative discussed in this EIS.

5.4 ENDANGERED SPECIES

The Endangered Species Act requires each Federal agency to ensure that any action it authorizes, funds, or carries out does not jeopardize endangered or threatened species (or those that are proposed as such) or result in the destruction or adverse modification of designated critical habitat. Federal agencies are required to consult with FWS and/or NMFS regarding the implementation of a proposed action. If FWS or NMFS indicates that an endangered or threatened species or critical habitat could be present in the

area of the proposed action, a biological assessment must be prepared. This assessment is used as a basis for evaluating the effects on Federally-protected species through the formal consultation process.

Formal consultations were held between DOE and FWS to comply with the Endangered Species Act of 1973. Based on these consultations, FWS issued a biological opinion that the preferred alternative cooling systems should have no effect on the American alligator, red-cockaded woodpecker, wood stork (Parker, 1986), or bald eagle (Henry, 1986). NMFS had previously concurred in DOE's determination that the population of the shortnose sturgeon in the Savannah River would not be adversely affected by SRP operations (Oravetz, 1983).

TC

5.5 WILDLIFE AND FISHERIES

Three regulations grant protection to wildlife and fisheries resources. These are the Fish and Wildlife Coordination Act, the Migratory Bird Treaty Act, and the Anadromous Fisheries Conservation Act. The Acts do not require application for or acquisition of a permit. However, each requires that DOE consult with FWS about impacts to fish and wildlife.

Consultations have been completed with FWS to ensure that DOE will comply fully with these three Acts. To assist in these consultations, a Habitat Evaluation Procedure (HEP) analysis was conducted which identified the value of habitat to be gained or lost with the potential implementation of the cooling water alternatives (Mackey et al., 1987).

BC-3
BD-4

5.6 WATER QUALITY

Section 402 of the Federal Water Pollution Control Act, as amended, is the basis for controlling "point source" discharges of pollutants into navigable waters of the United States through the National Pollutant Discharge Elimination System (NPDES). This system is administered by EPA, which has delegated NPDES permitting authority in South Carolina to SCDHEC.

[J.V.]

The following sections discuss the applicable State of South Carolina water classification standards, requirements, and water quality permits associated with the implementation of alternative cooling water systems for K- and C-Reactors and the D-Area coal-fired powerhouse.

Water Classification Standards

The State of South Carolina Class B water classifications standards (Regulation 61-68) applicable to the implementation of the cooling water alternatives include the following limits on the temperature of thermal effluents:

- Section D(8)(a) - The water temperature of all Class A and Class B free flowing waters shall not be increased more than 2.8°C above natural temperature conditions or exceed a maximum of 32.2°C as a result of the discharge of heated liquids unless a different temperature standard, as provided for in Section E, has been established, a mixing

zone as provided in D(5) has been established, or a Section 316(a) determination under the Federal Water Pollution Control Act, as amended, has been completed.

- Section D(9) - The numeric standards of Section D and Section E of this regulation are applicable to any flowing waters when the flow rate is equal to or greater than the minimum 7-day average flow rate that occurs with an average frequency of once in 10 years (7Q10). Uses will be protected to the greatest extent possible, regardless of flow.
- Section D(5)(a) - Mixing zones that are used for wastewater treatment effluents shall allow safe passage of aquatic organisms, and shall allow for the protection and propagation of a balanced indigenous population of aquatic organisms in and on the water body. The mixing zone size shall be based on critical flow conditions. The mixing zone shall not be an area of wastewater treatment nor shall it interfere with or impair existing recreational uses, existing drinking water supply uses, existing industrial or agricultural uses, or existing or potential shellfish harvesting uses.

Requirements

On January 3, 1984, DOE and SCDHEC mutually agreed on a Consent Order (84-4-W) that temporarily superseded the temperature requirements of the NPDES permit and established a process for SRP thermal discharge compliance with the State of South Carolina's water classification standards. This Consent Order was modified August 27, 1985, to include an implementation schedule for the selected cooling water systems. Due to extensive comments on the draft Environmental Impact Statement for the alternative cooling water system, additional time was needed by DOE to address the comments, resulting in an August 1987 amendment to 84-4-W which provides a revised schedule. Major requirements contained in the amended Consent Order and their status are summarized below.

Comprehensive Cooling Water Study: Required by NPDES permit as Special Condition Part III, Number 8 - DOE began a 2-year Comprehensive Cooling Water Study (CCWS) with data collection during Fiscal Years 1984 and 1985 to evaluate the environmental effects of present intakes and releases of cooling water by SRP facilities. The CCWS has two primary objectives: The first objective is to quantify the environmental effects associated with the large-volume withdrawal and discharge of cooling water on the Plant. The second objective is to evaluate the significance of any environmental impacts attributed to cooling water intake and discharge.

E. I. du Pont de Nemours and Company and the Savannah River Ecology Laboratory are conducting the CCWS for DOE. Participating in the study in a review and advisory capacity are the State of South Carolina, the State of Georgia, the U.S. Environmental Protection Agency (Region IV), the U.S. Fish and Wildlife Service (Region IV), and the U.S. Army Corps of Engineers (South Atlantic Division).

An annual SRP report (Du Pont, 1985) contains historic data pertinent to the study's objectives and new data developed during fiscal year 1984. A

final report (Du Pont, 1987) documents additional data collected during fiscal year 1985 and conclusions. This EIS incorporates data from this study.

TL

Thermal Mitigation Study - In compliance with the Consent Order, a Thermal Mitigation Study (DOE, 1984) describing the cooling water systems that could be implemented for K- and C-Reactors and the D-Area coal-fired powerhouse was submitted to SCDHEC on October 3, 1984.

Implementation Schedule - As outlined in the amended Consent Order, plans and specifications for the selected cooling water systems, subject to the appropriation of funds by Congress, are to be submitted to SCDHEC on or before September 30, 1988. The Consent Order further provides for the start of construction of the selected cooling water systems for K-Reactor on or before February 28, 1990, with completion of the selected system for K-Reactor on or before December 31, 1992. The implementation schedule for the construction of the selected D-Area cooling water system is to be contained in a submittal of plans and specifications on or before March 31, 1988, and is to become enforceable after approval by SCDHEC. Within 2 months after completion of the cooling water systems, plans of study for successful 316(a) demonstrations are to be submitted to SCDHEC if the alternatives selected do not comply with the ΔT of 2.8°C above ambient temperature requirement.

TC

Permits - Before construction of the selected cooling water systems, DOE will submit the required wastewater construction permit applications to SCDHEC for its approval.

Construction of the pipeline and discharge sparging system for the D-Area direct-discharge alternative will require Section 10 and 404 permits from COE. Section 401 certification from SCDHEC will be required for this alternative to ensure that construction and operations-related discharges into navigable waters will comply with applicable water classification standards. If this alternative is selected, DOE will submit the necessary permit applications to COE for its approval and the required SCDHEC certification before construction.

DOE will submit plans of study for conducting Section 316(a) demonstration studies within 2 months after completion of the selected cooling water systems if the selected cooling water systems do not meet the delta- 2.8°C ambient temperature requirement (i.e., once-through cooling towers for K- and C-Reactors, and increased pumping to the raw water basin for the D-Area coal-fired powerhouse). The Section 316(a) demonstration studies will assess whether the thermal discharge conditions for the implemented cooling water systems will ensure the protection and propagation of a balanced indigenous population of fish and wildlife in and on the waters affected by the thermal discharge.

In addition to these permits, DOE will continue to report on a quarterly basis to the South Carolina Water Resources Commission surface- and groundwater use, including changes in surface-water withdrawals associated with the implementation of the selected cooling water systems.

5.7 FLOODPLAINS/WETLANDS

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A floodplain/wetlands assessment is presented in Appendix F. A notice of this floodplain/wetlands assessment appeared in the Federal Register on March 28, 1986 (51 FR 10654). A floodplain/wetlands determination will appear in the Federal Register after completion of this EIS.

5.8 AIR QUALITY

The authority for regulation of air emissions has been delegated by EPA to the SCDHEC Bureau of Air Quality Control. The Bureau issues construction and operating permits and performs Prevention of Significant Deterioration (PSD) reviews. Because existing facilities will supply steam and electric power for any needed construction activities, no new SCDHEC operating permits will be required for K- and C-Reactors or the D-Area powerhouse.

The implementation of cooling towers for K- and C-Reactors will not emit any air contaminants that are regulated by an air emission permit.

EPA has retained jurisdiction for the regulation of airborne radionuclides. The Plant operates within the limits of the EPA's final regulations (50 FR 5190). The cooling water alternatives discussed in this EIS will be within these limits.

5.9 DEPARTMENT OF ENERGY HEALTH AND SAFETY ORDERS

DOE is responsible for ensuring the health and safety of its own facilities and has established comprehensive health, safety, and environmental programs. DOE Orders pertaining to the construction and operation of cooling water alternatives include:

- Order 3790.1, "Occupational Safety and Health Program for Federal Employees," December 11, 1980
- Order 5440.1C, "National Environmental Policy Act," April 9, 1985
- Order 5480.1B, "Environmental Protection, Safety, and Health Program for DOE Operations," September 23, 1986
- Order 5482.1B, "Environmental, Safety, and Health Appraisal Program," September 23, 1986
- Order 5483.1A, "Occupational Safety and Health Program for a Government Owned Contractor Operated Facility," June 22, 1983
- Order 5484.1, "Environmental Protection, Safety, and Health Protection Information Reporting Requirements," February 24, 1981
- Order 5700.6B, "Quality Assurance," September 23, 1986

TC

- Order 6430.1, "Department of Energy General Design Criteria Manual,"
December 12, 1983
- Order 5480.6, "Safety of Department of Energy-Owned Nuclear Reactors,"
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Lee, C. E. (State Historic Preservation Officer, South Carolina Department of Archives and History), 1986. Letter to R. S. Stern (U.S. Department of Energy, Office of Environmental Guidance, Washington, D.C.), Columbia, South Carolina.

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TC | Parker, W. T. (Field Supervisor, U.S. Department of the Interior, Endangered Species Field Station, Fish and Wildlife Service), 1986. Letter to C. G. Halsted (Assistant Manager, Health, Safety, and Environment, U.S. Department of Energy, Savannah River Operations Office), Log No. 4-2-86-204, Asheville, North Carolina.

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EIS RESPONSIBILITY Performed technical review of thermal effluent modeling in Appendix B and thermal performance sections in Chapter 2

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AFFILIATION NUS Corporation

EDUCATION B.S., Environmental Science, Florida Institute of Technology

EXPERIENCE Four years. Statutory/regulatory analysis, site-specific environmental compliance plans, environmental impact studies

TECHNICAL SPECIALTY

EIS RESPONSIBILITY Contributed to Chapter 5

NAME William E. Joyce

AFFILIATION NUS Corporation

EDUCATION B.S., Chemical Engineering, University of Connecticut

EXPERIENCE Eighteen years. Environmental impact studies, radiological dose impacts

TECHNICAL SPECIALTY

EIS RESPONSIBILITY Performed technical reviews of Appendixes B, D, and G

NAME John M. Koerner

AFFILIATION NUS Corporation

EDUCATION Ph.D. Residency, Geography/Geology, University of Michigan
M.A., Geography/Conservation, University of Colorado
B.A., Geography/Botany, University of Michigan

EXPERIENCE Twenty-three years. Environmental impact studies, environmental planning, terrestrial ecology, geomorphology, remote sensing, field surveys and mapping, demographics, permitting, public/legal involvement

TECHNICAL SPECIALTY

EIS RESPONSIBILITY Performed technical review of physical science sections in Chapters 3 and 4

NAME Barton C. Marcy, Jr.

AFFILIATION NUS Corporation

EDUCATION M.S., Zoology-Ichthyology, University of Connecticut
B.S., Biology, Wake Forest University

EXPERIENCE Twenty-three years. Environmental impact studies,
TECHNICAL SPECIALTY ichthyoplankton and entrainment studies, fisheries and
impingement, aquatic ecology, and marine biology

EIS RESPONSIBILITY Principal Investigator for draft EIS preparation.
Assistant Program Manager; principal technical reviewer
of draft and final EIS for NUS Corporation. Prepared
the Preface and Summary, Chapters 1 and 5, and Appendix
H; principal reviewer of aquatic ecology sections in
Chapters 3 and 4 and Appendixes C, I, and J.

NAME Geoff McGean

AFFILIATION NUS Corporation

EDUCATION B.A., Geography/Economics, Dartmouth College

EXPERIENCE One year. Community relations, socioeconomic impact
TECHNICAL SPECIALTY studies, demographic and economic analyses

EIS RESPONSIBILITY Prepared socioeconomic sections of Chapters 3 and 4

NAME David C. Navecky

AFFILIATION NUS Corporation

EDUCATION M.S., Water Resources Management, Michigan State
University
B.S., Environmental Science, Pennsylvania State
University

EXPERIENCE Four years. Hydrology/water quality baseline and
TECHNICAL SPECIALTY impact assessment studies

EIS RESPONSIBILITY Prepared hydrology sections of Chapter 3 and Section 4.5
(unavoidable/irreversible impacts)

NAME

Richard S. Nugent

AFFILIATION

NUS Corporation

EDUCATION

Ph.D., Marine Science, University of Miami
M.S., Biology, Boston College
B.S., Biology, Boston College

EXPERIENCE
TECHNICAL SPECIALTY

Nineteen years. Environmental impact studies, aquatic ecology, marine and estuarine ecology, water quality

EIS RESPONSIBILITY

Prepared descriptions of alternative cooling water system screening process in Chapter 2 and Appendix A, comparative impact sections in Chapters 2 and 4, and assisted in preparation of water quality impact sections in Chapter 4

NAME

Joseph F. O'Brien

AFFILIATION

NUS Corporation

EDUCATION

M.Engr., Water Resources Engineering, Clemson University
M.S., Chemistry-Organic, Lehigh University
B.A., Chemistry, Lehigh University

EXPERIENCE
TECHNICAL SPECIALTY

Thirteen years. Environmental impact and safety studies, rainfall-runoff analyses, water quality studies, water use studies, siting studies, flooding studies; groundwater hydraulics and transport

EIS RESPONSIBILITY

Prepared subsurface hydrology description for Chapter 3

NAME

James L. Oliver

AFFILIATION

NUS Corporation

EDUCATION

B.S., Biology, Murray State University

EXPERIENCE
TECHNICAL SPECIALTY

Fifteen years. Environmental research, limnological studies, thermal effects, ichthyoplankton and zooplankton studies, entrainment and impingement, fisheries ecology

EIS RESPONSIBILITY

Deputy Principal Investigator for draft EIS preparation. Principal Investigator for final EIS preparation. Aquatic ecology sections for Chapters 3 and 4 and Appendix C. Completed revision of the Summary and Chapter 1, primary reviewer of all sections FEIS

NAME William Lawrence Poppe

AFFILIATION NUS Corporation

EDUCATION Illinois Institute of Technology
University of Maryland

EXPERIENCE Thirty-three years. Surveying, civil engineering
TECHNICAL SPECIALTY (roads, earthwork, pipelines, drainage, erosion control), environmental studies, land planning

EIS RESPONSIBILITY Prepared cooling water alternative descriptions and resource utilization sections of Chapter 2

NAME Irwin J. Samec

AFFILIATION NUS Corporation

EDUCATION M.U.R.P., Urban and Regional Planning, Michigan State University
B.A., Sociology, Illinois Wesleyan University

EXPERIENCE Sixteen years. Environmental impact statements and
TECHNICAL SPECIALTY assessments, socioeconomic and land-use analyses, transportation studies, water resources and quality

EIS RESPONSIBILITY Principal technical reviewer of draft EIS for NUS Corporation

NAME Robert L. Schlegel

AFFILIATION NUS Corporation

EDUCATION Degree of Nuclear Engineering, Columbia University
M.S., Nuclear Engineering, Columbia University
B.S., Chemical Engineering, Massachusetts Institute of Technology

EXPERIENCE Twenty-one years. Radiological dose assessments,
TECHNICAL SPECIALTY environmental impacts

EIS RESPONSIBILITY Responsible for radiological characterization sections in Chapters 3 and 4 and Appendix G

<u>NAME</u>	Michael Septoff
<u>AFFILIATION</u>	NUS Corporation
<u>EDUCATION</u>	M.S., Meteorology-Oceanography, New York University B.S., Meteorology, City College of New York
<u>EXPERIENCE</u> <u>TECHNICAL SPECIALTY</u>	Eighteen years. Meteorology/air quality, data analyses, environmental impact statements, environmental safety analyses, licensing activities
<u>EIS RESPONSIBILITY</u>	Prepared characterization of meteorology and climatology for Chapter 3 and contributed to air quality impact section in Chapter 4

<u>NAME</u>	John O. Shipman
<u>AFFILIATION</u>	NUS Corporation
<u>EDUCATION</u>	B.A., English Literature, Georgetown University
<u>EXPERIENCE</u> <u>TECHNICAL SPECIALTY</u>	Twenty years. Publications management; technical writing and editing; environmental assessments and impact statements
<u>EIS RESPONSIBILITY</u>	Technical editor of the EIS

<u>NAME</u>	Robert L. Shoup
<u>AFFILIATION</u>	NUS Corporation
<u>EDUCATION</u>	Ph.D., Nuclear Physics, Florida State University B.S., Physics, Michigan State University
<u>EXPERIENCE</u> <u>TECHNICAL SPECIALTY</u>	Sixteen years. Environmental impact statements; environmental, safety analysis, and licensing activities
<u>EIS RESPONSIBILITY</u>	Primary reviewer of draft EIS for NUS Corporation

NAME Robert P. Solomon

AFFILIATION NUS Corporation

EDUCATION B.S., Forest Biology, State University of New York

EXPERIENCE Four years. Wetland assessment studies, computer-
TECHNICAL SPECIALTY compatible geographic data base systems, aerial photo interpretation

EIS RESPONSIBILITY Performed technical reviews of geography sections in Chapter 3

NAME Seshagiri Rao Tammara

AFFILIATION NUS Corporation

EDUCATION M.S., Chemical Engineering, University of Maryland
M.S., Environmental Engineering, University of Maryland
M.S., Chemical Engineering, Osmania University
(Hyderabad, India)
B.S., Chemical Engineering, Osmania University

EXPERIENCE Thirteen years. Environmental impact studies, cooling-
TECHNICAL SPECIALTY tower analyses, radiological impact and dose assessments, air quality impacts, thermal performance evaluations and thermal impacts

EIS RESPONSIBILITY Prepared cooling-tower air quality impacts sections in Chapter 4

NAME Jerry Tkac

AFFILIATION NUS Corporation

EDUCATION Towson State University
Frederick Community College

EXPERIENCE Nineteen years. Engineering design and drafting; site
TECHNICAL SPECIALTY planning and land development, storm water management, piping systems, highways, collection basins, building and equipment locations

EIS RESPONSIBILITY Prepared site maps for cooling water alternative descriptions in Chapter 2

NAME Alan L. Toblin
AFFILIATION NUS Corporation
EDUCATION M.S., Chemical Engineering, University of Maryland
 B.E., Chemical Engineering, The Cooper Union
EXPERIENCE Fifteen years. Hydrologic transport analyses
TECHNICAL SPECIALTY
EIS RESPONSIBILITY Prepared thermal performance sections of Chapter 2, cumulative thermal discharge effects in Chapter 4, and Appendix B

NAME Douglas D. Tuckhorn
AFFILIATION NUS Corporation
EDUCATION M.S., Mechanical Engineering, Tennessee Technological University
 B.S., Aeronautical Engineering, Embry Riddle Aeronautical University
EXPERIENCE Fourteen years. Cooling-system analyses, cooling towers, spray ponds, heat rejection cost-benefit studies, mechanical equipment specifications, plant retrofit design, equipment layouts and arrangements
TECHNICAL SPECIALTY
EIS RESPONSIBILITY Performed technical review of cooling water alternative descriptions and resource utilization sections of Chapter 2

NAME William R. Weiss
AFFILIATION NUS Corporation
EDUCATION M.S., Marine Science, University of South Florida
 B.S., Biology, Eastern College
EXPERIENCE Seventeen years. Aquatic ecology, water quality, environmental impact assessment including thermal and entrainment/impingement effects studies, natural resource management
TECHNICAL SPECIALTY
EIS RESPONSIBILITY Prepared descriptive sections for chlorination/dechlorination plans in Chapter 2, sections on environmental consequences to aquatic ecology and water quality/hydrology in Chapter 4, modifications/updates to aquatic ecology sections in Appendix C, all of Appendix I, and response to comments in Appendix J

<u>NAME</u>	Robert H. Werth
<u>AFFILIATION</u>	NUS Corporation
<u>EDUCATION</u>	B.A., Physics, Gordon College
<u>EXPERIENCE</u> <u>TECHNICAL SPECIALTY</u>	Twelve years. Environmental impact studies, sound level studies, noise impact assessments, air quality analysis, permitting
<u>EIS RESPONSIBILITY</u>	Prepared noise impacts sections in Chapter 4

<u>NAME</u>	Patricia L. Wherley
<u>AFFILIATION</u>	NUS Corporation
<u>EDUCATION</u>	B.A., Geography, The George Washington University
<u>EXPERIENCE</u> <u>TECHNICAL SPECIALTY</u>	Sixteen years. Environmental impact studies, demographics, land use and socioeconomic studies, regulatory analyses, public participation programs
<u>EIS RESPONSIBILITY</u>	Performed technical reviews of geography, archaeological historical, and socioeconomic sections of Chapter 3 and 4 and Appendixes E and H

<u>NAME</u>	Philip C. Whitney
<u>AFFILIATION</u>	NUS Corporation
<u>EDUCATION</u>	B.S., Civil Engineering, University of Maine
<u>EXPERIENCE</u> <u>TECHNICAL SPECIALTY</u>	Thirty-eight years. Heavy industrial/utility construction, design, and engineering
<u>EIS RESPONSIBILITY</u>	Performed technical review of cooling water alternative description and resource utilization sections of Chapter 2

<u>NAME</u>	William E. Wisenbaker
<u>AFFILIATION</u>	U.S. Department of Energy, Savannah River Operations Office
<u>EDUCATION</u>	M.B.A., Management, Georgia State University B.S., Chemistry, University of Georgia
<u>EXPERIENCE</u> <u>TECHNICAL SPECIALTY</u>	Twenty years. Air quality measurements, ecology, environmental impact assessment, compliance with regulations, environmental monitoring
<u>EIS RESPONSIBILITY</u>	Principal reviewer of EIS for DOE

<u>NAME</u>	Carl R. Yates
<u>AFFILIATION</u>	NUS Corporation
<u>EDUCATION</u>	M.S., Biology, West Virginia University B.S., Biology, University of Pittsburgh at Johnstown
<u>EXPERIENCE</u> <u>TECHNICAL SPECIALTY</u>	Four years. Radiological environmental monitoring programs, sample collection audits, land-use surveys, radiochemistry, aquatic ecology
<u>EIS RESPONSIBILITY</u>	Prepared descriptive radiological sections for Chapter 3 and Appendix D

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Nuclear Waste Program
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Protection Division
Brookhaven National Laboratory

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Hanford Technical Library
Battelle-Pacific Northwest
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Research Director
South Carolina Joint Legislative
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South Carolina Department of Health
and Environmental Control

Mr. H. M. Crapse
District Director
Lower Savannah District Office
South Carolina Department of Health
and Environmental Control

Mr. Hartsill W. Truesdale, Chief
Bureau of Solid and Hazardous
Waste Management
South Carolina Department of Health
and Environmental Control

Mr. James A. Joy, III, Chief
Bureau of Water Pollution Control
South Carolina Department of Health
and Environmental Control

Mr. William Harry Busbee
South Carolina Department
of Agriculture

Mr. Paul S. League
Legal Counsel
Water Resources Commission

Mr. Mac Smurthwaite
Associate Director
Economic Development
South Carolina State Development
Board

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South Carolina Coastal Council

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Deputy Commissioner
Environmental Quality Control
South Carolina Department of Health
and Environmental Control

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South Carolina Department of Health
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Bureau of Water Supply and
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Office of Energy Resources

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Mayor of Williston

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Jackson Town Council

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County Administrator
Aiken County

Mr. Edward E. Duryea
General Manager
Beaufort-Jasper County Water Authority

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Aiken County Planning Commission

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City of Aiken

City Administrator
City of North Augusta

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Greater Aiken Chamber of Commerce

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Georgia Environmental Protection
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Department of Natural Resources

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Program Coordination Branch
Environmental Radiation Programs
Environmental Protection Division
Department of Natural Resources

Mr. Jim Hardeman
Environmental Radiation Programs
Environmental Protection Division
Department of Natural Resources

Mr. Fred Lehman, Program Manager
Surface Water Supply
Department of Natural Resources

Mr. C. H. Badger, Administrator
Georgia State Clearinghouse
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Georgia State Department of Defense
Civil Defense Division

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Port Planning and Harbor
Development
Georgia Port Authority

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State Environmental and Location
Engineer
Department of Transportation

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Augusta

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Richmond County Extension Service

County Clerk
Columbia County

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Central Savannah River Area Planning
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GLOSSARY

absorbed dose

Energy transferred to matter when ionizing radiation passes through it. Absorbed dose is measured in rads.

absorption

The process by which the number and energy of particles or photons entering a body of matter are reduced by interaction with the matter.

acclimation

The acclimation or adaptation of a particular species over several generations to a marked change in the environment.

activity

A measure of the rate at which a material is emitting nuclear radiation, usually given as the number of nuclear disintegrations per unit of time. A unit of radioactivity is the curie (Ci), which equals 3.7×10^{10} disintegrations per second.

adsorption

The adhesion of a substance to the surface of a solid or solid particles.

AEC

Atomic Energy Commission. A five-member commission established by the Atomic Energy Act of 1954 to supervise the use of nuclear energy. The AEC was dissolved in 1975 and its functions transferred to the Nuclear Regulatory Commission (NRC) and the Energy Research and Development Administration (ERDA); ERDA became the U.S. Department of Energy (DOE) in 1977.

aerobic

Processes that can occur only in the presence of oxygen.

air quality

A measure of the levels of pollutants in the air.

air quality standards

The prescribed level of pollutants in the outside air that cannot be exceeded legally during a specified time in specified areas.

air sampling

The collection and analysis of air samples for detection or measurement of radioactive substances.

alluvial

Deposited by a stream or running water.

ambient air

The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. (It is not the air in immediate proximity to emission sources.)

anaerobic

Processes that occur in the absence of oxygen.

anion

A negatively charged ion.

AC-1 aquaculture

Culture of aquatic organisms

aquatic biota

The sum total of living organisms of any designated aquatic area.

aquifer

An underground bed or stratum of earth, gravel, or porous stone that contains water. The water can be pumped to the surface through a well or it might emerge naturally as a spring.

archaeological sites (resources)

Areas or objects modified or made by man and the data associated with these features and artifacts.

arenaceous limestone

Limestone with a texture or appearance of sand.

artifact

An object produced or shaped by human workmanship of archaeological or historic interest.

ash

Inorganic residue remaining after ignition of combustible substances.

atmosphere

The layer of air surrounding the earth.

backfill

Material used to refill an excavation.

background exposure

See exposure to radiation.

background radiation

Normal radiation present in the lower atmosphere from cosmic rays and earth sources. Background radiation varies considerably with location.

bedrock

Any solid rock exposed at the earth's surface or overlain by unconsolidated surface material such as soil, gravel, or sand.

benthos

The plant and animal life whose habitat is the bottom of a sea, lake, or river.

beta particle

An elementary particle emitted from a nucleus during radioactive decay. It is negatively charged, is identical to an electron, and is easily stopped by, for example, a thin sheet of metal.

bioaccumulation factor

Concentration of a substance (e.g., chemical or radionuclide) in fish flesh or other body parts divided by the concentration of that substance in the water in which the fish is living.

biocide

Chemical agent used to prevent or remove fouling organisms such as bacteria, fungi, algae, clams, etc., from entering or fouling intake and heat exchangers of powerplant/reactor cooling water systems.

biofouling

Aquatic organisms such as bacteria, fungi, algae, clams, etc., that colonize water-flow structures, often causing restricted water flow (i.e., cooling water systems of powerplants/reactors).

biological dose

The radiation dose, measured in rems, absorbed in biological material.

biosphere

The portion of the earth and its atmosphere capable of supporting life.

biostratigraphy

The study of stratigraphy via fossilized remains.

biota

The plant and animal life of a region.

blowdown

Water discharged from a recirculating cooling system to control concentration of salts or other impurities.

BOD

Biological oxygen demand, the oxygen required for oxidation of soluble organic matter by bacterial action in the presence of oxygen.

Btu

British Thermal Unit, a unit of heat; the quantity of heat required to raise the temperature of 1 pound of water by 1 degree Fahrenheit. One Btu equals 1055 joules (or 252 calories).

°C

Degree Celsius. The Celsius temperature scale is related to the Fahrenheit scale as follows:

$$^{\circ}\text{F} = ^{\circ}\text{C} \times \frac{9}{5} + 32$$

cancer

The name given to a group of diseases that are characterized by uncontrolled cellular growth.

carbon monoxide

A colorless, odorless gas that is toxic if breathed in high concentration over a certain period of time. It is a normal component of most automotive exhaust systems.

carcinogen

An agent capable of producing or inducing cancer.

carcinogenic

Capable of producing or inducing cancer.

Carolina bay

Wetland area found on the Southeastern Atlantic coastal plain; a shallow depression.

cc

Cubic centimeters, cm^3 or cc (1 cc = 1 milliliter).

CCDF

Complementary cumulative distribution function.

Ci

See curie.

clastic dike

A sedimentary dike formed by broken rocks from overlying or underlying material.

cold shock

A rapid decrease in water temperature that may result in fish mortality.

concentration

The amount of a substance contained in a unit quantity of a sample.

condensate

Water obtained by cooling the steam (overheads) produced in an evaporator system. Also, any liquid obtained by cooling saturated vapor.

CO₂

Carbon dioxide, a colorless, odorless, nonpoisonous gas that is a normal component of the ambient air.

coolant

A substance, usually water, circulated through a processing plant to remove heat.

cooling tower

A structure designed to cool water by evaporation. In this EIS, the water being cooled absorbs heat to condense the steam in the evaporator system.

correlatable

Able to establish a connection between geological formations or events.

Cretaceous

End of Mesozoic era, between 136 and 65 million years ago.

crystalline metamorphic rock

Rock consisting wholly of crystals.

cumulative effects

Additive environmental, health, and socioeconomic effects that result from a number of similar activities in an area.

curie (Ci)

A unit of radioactivity equal to 3.7×10^{10} (37 billion) disintegrations per second. A curie is also a quantity of any nuclide or mixture of nuclides having one curie of radioactivity.

daughter

A nuclide formed by the radioactive decay of another nuclide, which is called the parent.

decay heat

The heat produced by the decay of radioactive nuclides.

decay, radioactive

The spontaneous transformation of one nuclide into a different nuclide or into a different energy state of the same nuclide. The process results in the emission of nuclear radiation (alpha, beta, or gamma).

decomposition

The breakdown of a substance into its constituent parts.

delta T (ΔT)

Change in temperature.

TC

demography

The statistical study of human populations including size, density, distribution, and vital statistics such as age, sex, and ethnicity.

depauperate

Poor or impoverished, falling short of what occurs naturally; i.e., reduced numbers and species of biological organisms.

depositional regimes

A systematic laying or throwing down of material over a substantial area.

detector

Material or device (i.e., instrument) that is sensitive to radiation and can produce a response signal suitable for measurement or analysis.

detritus

Dead organic tissues and organisms in an ecosystem.

distillation

Separation process achieved by creating two or more coexisting zones that differ in temperature, pressure, or composition.

DOE

United States Department of Energy.

dose

The energy imparted to matter by ionizing radiation. The unit of absorbed dose is the rad, equal to 0.01 joules per kilogram of irradiated material in any medium.

dose commitment

The dose that an organ or tissue receives during a specified period of time (e.g., 50 or 100 years) as a result of intake (by ingestion or inhalation) of one or more radionuclides from 1 year's release.

dose equivalent

A term used to express the amount of effective radiation when modifying factors have been considered. It is the product of absorbed dose (rads) multiplied by a quality factor and any other modifying factors. It is measured in rems (Roentgen equivalent man).

dose rate

The radiation dose delivered per unit time (e.g., rems per year).

dosimeter

A small device (instrument) that measures radiation dose (e.g., film badge or ionization chamber) and is carried by a radiation worker.

drift

Mist or spray carried out into the atmosphere with the effluent air from cooling towers.

DWPF

Defense Waste Processing Facility, under construction at the Savannah River Plant. It is designed to process defense waste into a suitable form for terminal storage or disposal.

D₂O

Deuterium oxide or heavy water.

ecology

The science dealing with the relationship of all living things to each other and to the environment.

ecosystem

A complex of the community of living things and the environment forming a functioning whole in nature.

EDC

See environmental dose commitment.

effluent

Liquid waste discharged into the environment, usually into surface streams. In this EIS, effluent refers to discharged wastes that are nonpolluting in their natural state or as a result of treatment.

effluent standards

Defined limits of waste discharge in terms of volume, content of contaminants, temperature, etc.

EIS

Environmental impact statement, a document prepared pursuant to Section 102(2)(c) of the National Environmental Policy Act (NEPA) of 1969 for a major Federal action significantly affecting the quality of the human environment.

electron

An elementary particle with a unit negative charge and a mass $1/1837$ of the proton. Electrons surround the positively charged nucleus and determine the chemical properties of the atom.

element

One of the 105 known chemical substances that cannot be divided into simpler substances by chemical means. All nuclides of an element have the same atomic number.

emission standards

Legally enforceable limits on the quantities and kinds of air contaminants that may be emitted into the atmosphere.

endangered species

Plants and animals in an area that are threatened with either extinction or serious depletion.

energy

The capacity to produce heat or do work. Electrical energy is measured in units of kilowatt-hours.

entrainment

The capture and inclusion of organisms in the cooling water systems of powerplants/reactors. The organisms involved are generally 9 to 13 millimeters long, depending on the intake screen mesh size, and include phyto- and zooplankton, fish eggs and larvae (ichthyoplankton), shellfish larvae, and other forms of aquatic life.

environment

The sum of all external conditions and influences affecting the life, development, and ultimately, survival of an organism.

environmental dose commitment (EDC)

A dose representing exposure to, and ingestion of, environmentally available radionuclides for 100 years following 1 year's release of radioactivity.

environmental fate

The result of the physical, biological, and chemical interactions of a substance released to the environment.

environmental transport

The movement through the environment of a substance; it includes the physical, chemical, and biological interactions undergone by the substance.

Eocene

Lower Tertiary Period, after Paleocene but before Oligocene.

epoch

Length of time (geology).

erosion

The process in which uncovered soil and clay are carried away by the action of wind or water.

estuarine

Pertaining to an area where salt and fresh water come together and are affected by tides.

exposure to radiation

The incidence of radiation on living or inanimate material by accident or intent. Background exposure is the exposure to natural background ionizing radiation. Occupational exposure is the exposure to ionizing radiation that takes place during a person's working hours. Population exposure is the exposure to a number of persons who inhabit an area.

°F

degree Fahrenheit. The Fahrenheit temperature scale is related to the Celsius scale as follows:

$$^{\circ}\text{C} = \frac{(^{\circ}\text{F} - 32)}{1.8}$$

fall line

Imaginary line marking the point that most rivers drop steeply from the uplands to the lowlands.

fallout

The descent to earth and deposition on the ground of particulate matter (which might be radioactive) from the atmosphere.

fault

A fracture or a zone of fractures within a rock formation along which vertical, horizontal, or transverse slippage has occurred.

faunal

Animal and plant fossils of a certain rock unit.

feldspar

Most common group of aluminum silicate minerals (containing other metals, such as potassium, sodium, and iron) that form rock.

ferruginous

Containing iron oxide.

fission

The splitting of a heavy atomic nucleus into two approximately equal parts, which are nuclei of lighter elements, accompanied by the release of energy and generally one or more neutrons. Fission can occur spontaneously or can be induced by neutron bombardment.

fission products

Nuclei formed by the fission of heavy elements (primary fission products). Also, the nuclei formed by the decay of the primary fission products, many of which are radioactive.

fluvial

Relating to, or living in or near, a river.

flux

Rate of flow through a unit area.

food chain

The pathways by which any material entering the environment passes from the first absorbing organism through plants and animals to humans.

fuel

A substance used to produce heat (e.g., from chemical energy by combustion, or from nuclear energy by nuclear fission).

gal

Gallon.

gamma rays

High-energy, short-wave length electromagnetic radiation accompanying fission and emitted from the nucleus of an atom. Gamma rays are very penetrating and require dense (e.g., lead) or a thick layer of materials for shielding.

gamma spectrometry

Identification and quantification of radioisotopes by measurement of the characteristic gamma rays emitted by elements undergoing radioactive decay.

g/cm²

Grams per square centimeter, a measure of pressure. Atmospheric pressure is about 1055 g/cm².

genetic effects

Radiation effects that can be transferred from parent to offspring; radiation-induced changes in the genetic material of sex cells.

geology

The science that deals with the earth: the materials, processes, environments, and history of the planet, especially the lithosphere, including the rocks and their formation and structure.

g/L

Grams per liter.

glauconitic

Mineral aggregate containing glauconite, giving it a green color.

gneiss

Rock formed from bands of granular minerals alternating with bands of minerals that are flaky, or have elongate prismatic habits.

gradient

Slope, particularly of a stream or land surface.

groundwater

The supply of water under the earth's surface in an aquifer.

gypsum

Mineral containing hydrous calcium sulfate.

half-life (effective)

The time required for a radionuclide contained in an organism to reduce its activity by one half as a combined result of radioactive decay and biological elimination.

halogens

The group of five chemically related nonmetallic elements that include fluorine, chlorine, bromine, iodine, and astatine.

hardwoods

Trees that are angiosperms and yield wood that has a hard consistency.

health physics

The science concerned with recognition, evaluation, and control of health hazards from ionizing radiation.

heat exchanger

A device that transfers heat from one fluid (liquid or gas) to another or to the environment.

heavy metals

Metallic elements of high molecular weight, such as mercury, chromium, cadmium, lead, and arsenic, that are toxic to plants and animals at known concentrations.

heavy water

Water in which the molecules contain oxygen and deuterium, an isotopic form of hydrogen that is heavier than ordinary hydrogen.

high-level waste

High-level liquid waste or the products from the solidification of high-level liquid waste or irradiated fuel elements if discarded without reprocessing.

historic resources

The sites, districts, structures, and objects considered limited and nonrenewable because of their association with historic events or persons, or social or historic movements.

holding pond

A pond constructed to retain water from a cooling water system before release to a water body.

Holocene

Epoch of Quaternary Period from end of Pleistocene to present time.

hydraulic conductivity

Water flow rate in liters per day through a 1-square-foot cross-section under a unit hydraulic gradient.

hydraulic (water) head

Height of water with a free surface above a subsurface point.

hydrocarbons (HC)

Organic compounds consisting primarily of hydrogen and carbon. Hydrocarbons are emitted in automotive exhaust and from the incomplete combustion of fossil fuels such as coal.

hydrograph

Graph showing water characteristics such as velocity, or flow, in relation to time.

hydrology

The science dealing with the properties, distribution, and circulation of natural water systems.

hydrosphere

The water portion of the surface of the earth as distinguished from the solid portion, the lithosphere.

hydrostratigraphic unit

Rock or soil body extending laterally for a considerable distance; sometimes abbreviated HSU.

ichthyoplankton

The early life stages of fish (eggs and larvae) that spend part of their life cycle as free-floating plankton.

impingement

The process by which aquatic organisms too large to pass through the intake screens of a powerplant/reactor become caught on the screens and unable to escape.

incorporated places

Political units incorporated or combined as cities, boroughs, towns, and villages.

indigenous labor pool

An area's native labor pool composed of workers normally residing in the area who do not leave the area after termination of a construction project.

induced radioactivity

Radioactivity that is created when substances are bombarded with neutrons, as in a reactor.

inert gas

A gas that is totally unreactive.

in-movers

Workers who move into an area during construction and leave when the project is finished. As referred to in this document, in-movers also include some weekly travelers.

insolation

Solar radiation incident on the water surface.

intensity

The energy or the number of photons or particles of radiation incident on a unit of time. Intensity of radioactivity is the number of atoms disintegrating per unit of time.

interfluvial

Falling in the area between two streams.

ion

An atom or molecule that has gained or lost one or more electrons and thus has become electrically charged.

ion exchange
Process in which a solution containing soluble ions to be removed is passed over a solid ion exchange column, which removes the soluble ions by exchanging them with labile ions from the surface of the column. This process is reversible; the trapped ions can be eluted from the column and the column regenerated.

ionization
The process whereby ions are created. Nuclear radiation can cause ionization, as can high temperatures and electric discharges.

ionizing radiation
Radiation capable of displacing electrons from atoms or molecules, thereby producing ions.

irradiation
Exposure to radiation.

isotope
An atom of a chemical element with a specific atomic number and atomic weight. Isotopes of the same element have the same number of protons but different numbers of neutrons.

kaolin
Clay mineral group characterized by a silicon oxygen sheet and an aluminum-hydroxyl sheet alternately linked to form a two-layer crystal lattice.

kilometer
A metric unit of length equal to 0.62137 mile.

leachate
Liquid that has percolated through solid waste or other media and has extracted from the solids dissolved or suspended materials into the liquids.

leaching
The process whereby a soluble component of a solid or mixture of solids is extracted as a result of percolation of water around and through the solid.

leukemia
A form of cancer characterized by extensive proliferation of nonfunctional, immature white blood cells (leukocytes).

lignite
A brownish-black coal between stages of peat and sub-bituminous coal.

limonite
Hydrous ferric oxides occurring naturally but having unknown origins.

liters per second

A metric unit of flow rate equal to 15.85 gallons per minute.

lithology

Rock descriptions by color, structure, grain size, etc.

lithosphere

The solid part of the earth composed predominantly of rock.

long-lived nuclides

Radioactive isotopes with half-lives greater than 30 years.

lps

Liters per second.

m^3/m

Cubic meters per minute.

m^3/s

Cubic meters per second.

macroinvertebrates

Those invertebrates that can be seen by the unaided eye that are retained in a U.S. Standard sieve (0.595 millimeters).

BB-4

macrophytes

Aquatic plants that can be either submerged or emergent.

marine terrace

Narrow coastal strip altered by marine deposit and erosion.

maximum permissible dose

That dose of ionizing radiation established by competent authorities as an amount below which there is no appreciable risk to human health; at the same time, it is below the lowest level at which a definite hazard exists.

mechanical draft (cooling tower)

A type of cooling tower that uses fans to provide air flow for promoting evaporative cooling (see natural draft).

megawatt (MW)

A unit of power equal to 1000 kilowatts (kW) or 1 million (10^6) watts.

mg

Milligram (one-thousandth of a gram).

mica

Variously colored, or colorless mineral silicates, crystallizing in monoclinic forms that separate into thin leaves.

micro (μ)

Prefix indicating one millionth. One microgram equals one-millionth of a gram or 10^{-6} gram.

micrometer (μm)

A unit of length equal to one one-millionth (10^{-6}) of a meter.

micron

A micrometer (10^{-6} meter).

migration

The natural travel of a material through the air, soil, or groundwater.

ml

Milliliter (one-thousandth of a liter).

mm

Millimeter (one-thousandth of a meter).

mobility

The ability of a chemical element or a pollutant to move into and through the environment.

moderator

A material used to slow neutrons from fission to thermal energies.

molecule

A group of atoms held together by chemical forces. A molecule is the smallest unit of a compound that can exist by itself and retain all its chemical properties.

monitoring

Process whereby the level and quality of factors that can affect the environment and human health are measured periodically to regulate and control potential impacts.

mrem

Millirem (one-thousandth of a rem).

mutagen

Physical, chemical, or radiative agent capable of inducing mutation (above the spontaneous background level).

mutagenesis

The occurrence or induction of mutation, a genetic change that is passed on from parent to offspring.

mutation

An inheritable change in the genetic material (in a chromosome).

nano
Prefix indicating one thousandth of a micro unit; one trillionth;
1 nanocurie = 10^{-9} curie.

National Register of Historic Places

A list maintained by the National Park Service of architectural, historic, archaeological, and cultural sites of local, state, or national significance.

natural draft (cooling tower)

A type of cooling tower that relies on the difference in density between the entering air and internal heated air to provide air flow for promoting evaporative cooling (see mechanical draft).

natural radiation or natural radioactivity
Background radiation.

nCi
Nanocuries, 10^{-9} curies.

NEPA

National Environmental Policy Act of 1969.

neutron

An uncharged elementary particle with a mass slightly greater than that of the proton and found in the nucleus of every atom heavier than hydrogen. A free neutron is unstable and decays with a half-life of about 13 minutes into an electron and a proton.

neutron flux

Number of neutrons flowing through a specified area per unit of time.

NH₃

Ammonia, a pungent, reactive colorless gas, which is irritating to the eyes and moist skin in high concentrations.

NO_x

The oxides of nitrogen, primarily NO and NO₂. These are often produced in the combustion of fossil fuels. In high concentration they constitute an air pollution problem.

nodes

The intersection of horizontal and vertical grids.

NRC

U.S. Nuclear Regulatory Commission.

nuclear energy

The energy liberated by a nuclear reactor (through fission or fusion) or by radioactive decay.

nuclear powerplant

A facility that converts nuclear energy into electrical power. Heat produced by a reactor is used to make steam to drive a turbine that drives an electric generator.

nuclear reaction

A reaction in which an atomic nucleus is transformed into another element, usually with the liberation of energy as radiation.

nuclear reactor

A device in which a fission chain reaction is maintained and which is used for irradiation of materials or the generation of electricity.

nucleus

The small, positively charged core of an atom that contains nearly all of the atom's mass.

nuclide

An atomic nucleus specified by its atomic weight, atomic number, and energy state. A radionuclide is a radioactive nuclide.

once-through (cooling system)

A cooling system that utilizes water from a river one time for cooling and then returns it to the river.

organic degreasers

Cleaning agents having organic chemical structures.

outcrop

Part of a geologic formation above the surface of the earth.

Paleocene

Epoch of Tertiary Period between the Gulfian of the Cretaceous Period and before the Eocene.

particulates

Solid particles small enough to become airborne.

pD

The negative log of the deuterium (heavy hydrogen) ion concentration in solution; analogous to the term pH, which refers to the normal hydrogen ion concentration.

penneplain

Almost featureless, plain land surface.

perched

A water-bearing area of small lateral dimensions lying above a more extensive aquifer.

periphyton

Plankton (attached) plants that occur in water.

BB-4

permeability

Ability of water to flow through porous rock or soil.

person-rem

The radiation dose commitment to a given population; the sum of the individual doses received by a population segment.

pH

A measure of the hydrogen ion concentration in aqueous solution; specifically, the negative logarithm of the hydrogen ion concentration. Acidic solutions have a pH from 0 to 7; basic solutions have a pH greater than 7.

photon

Electromagnetic radiation; a quantum of electromagnetic energy having properties of both a wave and a particle but without mass or electric charge.

physiography

Description of earth surface features, including air and water as well as land.

BB-4

phytoplankton

Planktonic (floating) plants that occur in water.

Piedmont province

Large area forming a plateau at the base of the Appalachian mountains, extending from New Jersey to Alabama.

piezometric maps

Lines of equal groundwater pressure drawn on a map.

piezometric surface

The surface to which water in an aquifer would rise by hydrostatic head.

Plant stream

Any natural stream on the Savannah River Plant. Surface drainage of the Plant is via these streams to the Savannah River.

Pleistocene

An epoch of the Quaternary Period between Pliocene and Holocene.

Pliocene

An epoch of the Tertiary Period between Miocene and Pleistocene.

plume

The visible emission into the air from a flue, chimney, or cooling tower. Also, a segment or area within a body of water that has measurably distinct characteristics (e.g., higher temperatures as from heated effluent).

pollution

The addition of any undesirable agent to an ecosystem in excess of the rate at which they can be degraded, assimilated, or dispersed by natural processes.

ppb

Parts per billion (10^{-9}); one thousandth of a part per million.

ppm

Parts per million. This unit is commonly used to represent the degree of pollutant concentration when the concentration is small. In air, ppm is usually volume pollutant per one million volumes of air; in water, a weight per one million weight units.

primary road

Interstate, state, and regional routes including rural arterial routes and their extensions into or through urban areas.

pyrite

Isometric mineral: FeS_2 (iron sulfide).

quality factor

The factor by which absorbed dose, in rads, is multiplied to obtain a quantity expressing the irradiation incurred by various biological tissues taking into account the biological effectiveness of the various types of radiation.

quartz

Crystalline silica: SiO_2 .

quartzite

Very hard, metamorphosed sandstone.

Quaternary age

The period from the end of the Tertiary age to the present.

rad

Acronym for radiation absorbed dose, the basic unit of absorbed dose equal to the absorption of 0.01 joule per kilogram of absorbing material.

radiation

The emitted particles and photons from the nuclei of radioactive atoms. Some elements are naturally radioactive whereas others are induced to become radioactive by bombardment in a reactor. Naturally occurring radiation is indistinguishable from induced radiation.

radiation detection instrument

Devices that detect and record the characteristics of ionizing radiation.

radiation monitoring

Continuous or periodic determination of the amount of radiation present in a given area.

radiation protection

Legislation, regulations, and measures to protect the public and industrial laboratory workers from harmful exposure to radiation.

radiation shielding

Reduction of radiation by interposing a shield of absorbing material between a radioactive source and a person, laboratory area, or radiation-sensitive device.

radiation standards

Permissible exposure levels of radiation and regulations governing same.

radioactivity

The spontaneous decay or disintegration of unstable atomic nuclei, accompanied by the emission of radiation.

radioisotopes

Nuclides of the same element (same number of protons in their nuclei) that differ in the number of neutrons and that spontaneously emit particles or electromagnetic radiation.

receiving waters

Rivers, lakes, oceans, or other bodies of water into which treated or untreated wastewaters are discharged.

recirculating (cooling system)

A cooling system that uses the same water cyclically to absorb heat and be cooled again. A percentage of new water must be added continuously to make up for evaporative and blowdown losses.

rem

Acronym for roentgen equivalent man, the unit of dose for biological absorption. It is equal to the product of the absorbed dose in rads, a quality factor, and a distribution factor.

residence time

The period of time during which a substance resides in a designated area.

roentgen (R)

A unit of exposure to ionizing radiation equal to or producing one coulomb of charge per cubic meter of air.

runoff

The portion of rainfall, melted snow, or irrigation water that flows across ground surface and eventually is returned to streams. Runoff can carry pollutants into receiving waters.

sandstone

Clastic rock containing large, individual particles visible to the unaided eye.

sanitary landfilling

An engineered method of solid waste disposal on land in a manner that protects the environment. Waste is spread in thin layers, compacted to the smallest practical volume, and covered with soil at the end of each working day.

SCDHEC

South Carolina Department of Health and Environmental Control

screen

Tool used to allow particles of a certain size through while retaining larger particles.

secondary road

A rural, major collector route.

sedimentation

The settling of excess soil and mineral solids of small particle size contained in water.

seep lines

Small zone where water leachate percolates slowly to the surface; a series of groundwater or leachate springs.

seismic

Pertaining to any earth vibration, especially an earthquake.

seismicity

The tendency toward the occurrence of earthquakes.

settling tank

A tank in which settleable solids are removed by gravity.

sewage

The total of organic waste and wastewater generated by an industrial establishment or a community.

sewer

Any pipe or conduit used to collect and carry away sewage or stormwater runoff.

sewerage

The entire system of sewage collection, treatment, and disposal.

shield

An engineered body of absorbing material used to protect personnel from radiation.

short-lived nuclides

Radioactive isotopes with half-lives no greater than about 30 years (e.g., cesium-137 and strontium-90).

siliceous cement

Cement with an abundance of silica.

siltstone

Silt having the texture and composition of shale, but lacking its fine lamination.

sink

An area from which water drains or is removed.

sludge

The precipitated solids (primarily oxides and hydroxides) that settle to the bottom of the storage tanks containing liquid high-level waste.

slug

Small, isolated body of water.

slurry

A suspension of solid particles (sludge) in water.

softwoods

Trees, particularly evergreens and shrubs, that produce seeds in a cone.

SO₂

Sulfur dioxide, a heavy pungent colorless gas (formed in the combustion of coal). SO₂ in high concentration is considered a major air pollutant.

SO_x

The oxides of sulfur, primarily SO₂ and SO₃. SO_x is a common air pollutant.

sparger

A discharge nozzle that provides quick dispersion of one fluid (liquid or gas) into another.

spill

The accidental release of radioactive material.

spray irrigation

The practice of dispersing treated aqueous effluents by spraying land in controlled amounts. Treated effluent is rich in nutrients that can be utilized by plants.

SREL

Savannah River Ecological Laboratory, an ecology research institution operated by the University of Georgia under contract from DOE.

SRL

Savannah River Laboratory.

SRP
Savannah River Plant.

stable
Not radioactive.

stack
A vertical pipe or flue designed to exhaust gases and suspended particulates.

stack gases
Gases emitted from a stack.

stationary source
A source of emissions into the environment that is fixed rather than moving, as an automobile.

storage
Retention of radioactive waste in manmade containment, such as a tank or vault, in a manner permitting retrieval; distinguished from disposal, which implies no retrieval.

storage coefficient
Volume of water released from storage in a vertical column of 0.93 square meter when the water table declines 0.93 meter.

stratified
Formed or arranged in layers.

stratigraphy
Division of geology dealing with the definition and description of rocks and soil of both major and minor natural divisions.

study area
A specific geographic area isolated from surrounding areas for the purpose of examining and analyzing specific phenomena and activities.

surface water
All water on the surface, as distinguished from groundwater.

surficial deposit
Most recent geological deposit lying on bedrock or on or near the earth's surface.

Tertiary age
First period of Cenozoic era, thought to be between 65 and 2 million years ago.

thermal pollution
Degradation of water quality by introduction of a heated effluent.

threshold dose

The minimum dose of a given substance that produces a measurable environmental factor.

tolerance

The relative capability of an organism to endure an unfavorable environmental factor.

topography

The configuration of a surface area, including its relief or relative elevations and the position of its natural and manmade features.

toxicity

The quality or degree of being poisonous or harmful to plant or animal life.

transmissivity

The rate at which water of prevailing kinematic viscosity is transmitted through a unit width under a unit hydraulic gradient.

Triassic Period

First period of the Mesozoic era, thought to be between 225 and 190 million years ago.

tritium (H-3)

A radioactive isotope of hydrogen, a weak beta emitter with a half-life of 12.5 years.

TSP

Total suspended particulates, the concentration of particulates in suspension in the air irrespective of the nature, source, or size of the particulates.

turbidity

Measure of sediment or suspended foreign particle concentration in solution.

unconsolidated

Loosely arranged or unstratified sediment.

USGS

United States Geological Survey.

venting

Release of gases or vapors under pressure to the atmosphere.

waste heat

Heat in materials at temperatures that are close to ambient and hence not valuable for production of power. Waste heat must be discharged to the environment.

water pollution

Presence of one or more contaminants in such degree as to be detrimental to the intended use of the water.

watershed

The area drained by a stream.

water table

The upper surface of groundwater.

wetland

Land or areas containing much soil moisture.

BP-4
BC-19

zooplankton

Planktonic (floating) animals that supply food for fish.

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APPENDIX A

IDENTIFICATION OF COOLING WATER ALTERNATIVES FOR EVALUATION IN THE EIS

A.1 INTRODUCTION

This appendix describes the cooling water alternatives considered for K- and C-Reactors and the D-Area coal-fired powerhouse. It also discusses the process used to identify the cooling water alternatives that are evaluated in this environmental impact statement (EIS).

A.2 INITIAL ALTERNATIVES

As documented in the Thermal Mitigation Study (DOE, 1984), DOE initially considered two categories of cooling water alternatives: (1) those that would provide some reduction in the temperature of thermal discharges but that would not meet the 32.2°C Class B water classification standard of the State of South Carolina; and (2) those that could meet the 32.2°C water classification standard.

A.2.1 ALTERNATIVES NOT MEETING THE 32.2°C STANDARD

For alternatives that would not meet Class B water classification standards (such as rubble dams, small cooling lakes, and the current once-through cooling water systems), the South Carolina legislature and the U.S. Environmental Protection Agency (EPA) would have to approve a new stream classification (i.e., a change in the designation of several onsite streams from Class B to some other classification) after DOE had submitted a use attainability analysis in accordance with EPA regulations (40 CFR 131).

Because of the concern over both the applicability of EPA and State regulations that prohibit designating the use of a stream for waste transport or waste assimilation and the inapplicability of criteria contained in EPA's regulations [40 CFR 131.10(g)] by which a change in designated uses could be justified, DOE eliminated from further consideration those alternatives that would not meet Class B water classification standards.

The following items describe the initial cooling water alternatives for K- and C-Reactors that were eliminated:

- Spray canals. This alternative would add a gravity-powered spray cooling system to the cooling water outlets of K- and C-Reactors to cool the discharged water by spraying it into the air before it enters the receiving water body. Both the 68°C maximum discharge temperature and the 66°C average summer temperature would be only slightly below the water temperatures that result from direct discharge (i.e., 73°C and 71°C, respectively).
- Small lakes. This system would use five to ten small rubble dams each on Four Mile Creek and Pen Branch to create small lakes; it would

provide some thermal mitigation, compared to direct discharge, to the lower portions of these waterways and to the Savannah River swamp. Under extreme summer conditions, the 45°C discharge temperatures would represent a 28°C reduction below direct discharge (73°C), but they would not meet the 32.2°C temperature standard at any time during the year.

- Small lakes with upstream spray cooling (one set). This alternative is very similar to the small lakes alternative (above), but would include a gravity spray module in the outfall canal. It would result in some limited thermal mitigation in comparison to direct discharge, but would not provide much more cooling than the small lakes alternative alone. The 32.2°C water classification standard would not be met at any time during the year.
- Small lakes with upstream and downstream spray cooling (two sets). This alternative would add two gravity spray cooling modules to the basic small lakes alternative described above. The first spray system would obtain some cooling before the discharge water enters the receiving water body. The second spray module would be in the last shallow lake formed in either stream. The cooling from this system would be about 5°C greater than that resulting from the small lakes with upstream spray cooling (one set) described above. In comparison to direct discharge, this alternative would reduce water temperatures from 73°C to 39°C under extreme summer conditions and from 69°C to 34°C during the spring. It would be in compliance with the 32.2°C temperature limit only during the winter (29°C).
- Energy recovery systems. The systems that were considered included both onsite steam generation and the use of a Rankine cycle to generate electricity. The option of onsite steam generation would remove only 0.3 percent of the heat from the effluent stream, or a 0.3°C drop in effluent temperature at the outfall. The Rankine cycle would lower the effluent temperature from 71°C to 49°C. (See Appendix I for details.)

A.2.2 ALTERNATIVES MEETING THE 32.2°C STANDARD

For those alternatives that could meet the Class B water classification standards, DOE identified subcategories of potential generic cooling water systems for K- and C-Reactors and for the D-Area coal-fired powerhouse. The subcategories identified for K- and C-Reactors consisted of cooling towers, cooling lakes and ponds, and cooling lake/pond and cooling tower combinations. For the D-Area powerhouse, the subcategories included cooling towers, direct discharge to the Savannah River, and increased flow with mixing. DOE then developed minimum requirements for the identification in more detail of the specific alternatives in each subcategory. These requirements included sufficient surface area in cooling lakes or ponds for heat dissipation, and sufficient cooling capacity in once-through and recirculating cooling towers to attain a 32.2°C discharge temperature during extreme meteorological conditions.

Using these minimum requirements, DOE initially identified 22 potential cooling water alternatives for K- and C-Reactors and four alternatives for D-Area. The following list describes these alternatives:

K-Reactor Alternatives

- K-1 1400-acre once-through cooling lake between Pen Branch and Four Mile Creek above the railroad track
- K-2 1400-acre recirculating cooling lake between Pen Branch and Four Mile Creek above the railroad track
- K-3 1300-acre once-through cooling lake on Pen Branch with an embankment 1219 meters below Road C
- K-4 1300-acre recirculating cooling lake on Pen Branch with an embankment 914 meters below Road C
- K-5 Recirculating cooling tower
- K-6 Once-through cooling tower
- K-7 Once-through cooling tower to a 600-acre once-through cooling lake on Indian Grave Branch with an embankment about 305 meters above the confluence with Pen Branch
- K-8 800-acre cooling lake with a 400-acre hot arm to a once-through cooling tower with an embankment located about 610 meters above Road A on Pen Branch
- K-9 1600-acre once-through cooling lake with an embankment in the same location as the 800-acre lake with 400-acre hot arm (above)
- K-10 1700-acre once-through cooling lake on Pen Branch with an embankment about 2134 meters below Road C, and the reactor discharge pumped to the cooling lake

TC

C-Reactor Alternatives

- C-1 1200-acre once-through cooling lake on Four Mile Creek with an embankment about 1.6 kilometer above Road A
- C-2 1200-acre recirculating cooling lake on Four Mile Creek with an embankment about 1.6 kilometer above Road A
- C-3 1400-acre once-through cooling lake between Pen Branch and Four Mile Creek below the railroad track
- C-4 Recirculating cooling tower
- C-5 Once-through cooling tower

TC

- C-6 Once-through cooling tower to a 500-acre once-through cooling lake on a tributary of Four Mile Creek with an embankment about 305 meters above the confluence with Four Mile Creek
- C-7 800-acre cooling lake with a 400-acre hot arm to a once-through cooling tower with an embankment on Four Mile Creek about 1280 meters above Road A
- C-8 1700-acre once-through cooling lake on Four Mile Creek with an embankment about 1280 meters above Road A
- C-9 1700-acre once-through cooling lake on Four Mile Creek with an embankment about 152 meters above Road 4, and the reactor discharge pumped to the cooling lake

K- and C-Reactors Alternatives

- K/C-1 3000-acre recirculating cooling lake on Mill Creek with an embankment about 610 meters above the confluence with Tinker Creek
- K/C-2 3000-acre once-through cooling lake on Mill Creek with an embankment about 610 meters above the confluence with Tinker Creek

K-, C-, and L-Reactors Alternatives

- K/C/L-1 3000-acre once-through and recirculating cooling lake on Mill Creek with an embankment about 610 meters above the confluence with Tinker Creek

D-Area Powerhouse Alternatives

- D-1 Direct discharge to the Savannah River
- D-2 Once-through cooling tower
- D-3 Increased flow with mixing
- D-4 Recirculating cooling tower

A.3 SCREENING OF ALTERNATIVES

After the identification of the 26 cooling water alternatives that could meet Class B water classification standards, DOE used a screening process to determine which of these systems would be the most reasonable for implementation.

As documented in the Thermal Mitigation Study, the screening process consisted of the successive application of exclusionary criteria and discriminatory criteria. The application of "exclusionary" criteria led to the elimination of five cooling-lake alternatives for K- and C-Reactors. The "exclusionary" criteria are listed below:

1. The temperature of the receiving stream shall not exceed 32.2°C after mixing unless a Section 316(a) demonstration can be successfully performed.

2. The temperature of a receiving stream shall not be raised more than 2.8°C above ambient after mixing unless a Section 316(a) demonstration can be successfully performed.
3. Cooling lakes shall have a minimum surface area of 400 acres at a temperature of 32.2°C or less to support a successful Section 316(a) demonstration.
4. The average annual production loss shall be equal to or less than 10 percent for the purpose of screening.

This screening step eliminated the following alternatives:

No.	Alternative	Reasons for elimination
<u>K-Reactor</u>		
K-2	1400-acre recirculating cooling lake	Too small to provide needed cooling capacity
K-4	1300-acre recirculating cooling lake	Too small to provide needed cooling capacity
K-9	1600-acre once-through cooling lake	Hot arm of about 500 acres would not provide required cooling capacity
<u>C-Reactor</u>		
C-2	1200-acre recirculating cooling lake	Too small to provide needed cooling capacity
C-8	1700-acre once-through cooling lake	Hot arm of about 500 acres would not provide required cooling capacity

DOE screened the possible alternatives for the D-Area coal-fired powerhouse in the same manner as that used for the two reactors. However, it did not apply the criteria for maintaining a surface area of 400 acres at 32.2°C or less. The process found all four of the possible alternatives for the powerhouse to be feasible and eliminated none at this point.

The final step in the screening process was the application of the five "discriminatory" criteria listed below to identify "reasonable compliance alternatives":

1. Environmental impacts (i.e., thermal and flow effects resulting from the effluent discharge; habitat modifications such as impacts to wetlands and uplands; water quality; intake/discharge rates; impingement and entrainment; impacts to endangered and threatened species; and transport of radionuclides)

2. Implementation schedule (i.e., the estimated time to construct the alternative)
3. Costs (capital and operating)
4. Engineering and construction (i.e., the technical feasibility of engineering and constructing the alternative, such as pumping hot water over long distances, close approaches to wet bulb temperatures, non-standard engineering and construction techniques)
5. Relative operating complexity (i.e., multiple reactor cooling systems versus recirculation systems versus once-through systems)

After the application of the discriminatory criteria, DOE eliminated the following nine alternatives:

No.	Alternative	Reasons for elimination
<u>K-Reactor</u>		
K-3	1300-acre once-through cooling lake	Environmental impacts, production loss, relative costs
K-10	1700-acre once-through cooling lake	Environmental impacts, relative costs, scheduling
<u>C-Reactor</u>		
C-1	1200-acre once-through cooling lake	Environmental impacts, production loss, relative costs
C-9	1700-acre once-through cooling lake	Environmental impacts, relative costs, scheduling
<u>K- and C-Reactors Combined</u>		
K/C-1	3000-acre recirculating cooling lake	Relative costs, production loss, operating complexity, engineering considerations
K/C-2	3000-acre once-through cooling lake	Environmental impacts, operating complexity, relative costs
<u>K-, C-, and L-Reactors Combined</u>		
K/C/L-1	3000-acre once-through and recirculating cooling lake	Operating complexity, scheduling

No.	Alternative	Reasons for elimination
<u>D-Area Powerhouse</u>		
D-2	Once-through cooling tower	Relative costs, operating complexity compared to direct discharge
D-4	Recirculating cooling tower	Relative costs, operating complexity compared to direct discharge

As a result of the successive application of the exclusionary and discriminatory criteria, DOE identified the following alternatives as reasonable for implementation for K- and C-Reactors and the D-Area coal-fired powerhouse:

K-Reactor Alternatives

K-1	1400-acre once-through cooling lake between Pen Branch and Four Mile Creek above the railroad track	TC
K-5	Recirculating cooling tower	
K-6	Once-through cooling tower	
K-7	Once-through cooling tower to a 600-acre once-through cooling lake on Indian Grave Branch with an embankment about 305 meters above the confluence with Pen Branch	
K-8	800-acre cooling lake with a 400-acre hot arm to a once-through cooling tower with an embankment located about 610 meters above Road A on Pen Branch	

C-Reactor Alternatives

C-3	1400-acre once-through cooling lake between Pen Branch and Four Mile Creek below the railroad track	TC
C-4	Recirculating cooling tower	
C-5	Once-through cooling tower	
C-6	Once-through cooling tower to a 500-acre once-through cooling lake on a tributary of Four Mile Creek with an embankment about 305 meters above the confluence with Four Mile Creek	
C-7	800-acre cooling lake with a 400-acre hot arm to a once-through cooling tower with an embankment on Four Mile Creek about 1280 meters above Road A	

D-Area Powerhouse Alternatives

- D-1 Direct discharge to the Savannah River
- D-2 Increased flow with mixing

A.4 ALTERNATIVES CONSIDERED IN THIS EIS

As part of the scoping process, DOE invited interested parties to comment on the alternatives it would consider in this environmental impact statement (Federal Register, 50 FR 30728). Because of unfavorable topographic features in the areas around K- and C-Reactors and the resulting high capital costs for constructing large cooling lakes, DOE proposed that this statement consider only the once-through and recirculating cooling towers. In addition, DOE proposed that it not perform a detailed evaluation of the alternative calling for direct discharge of D-Area effluents to the Savannah River because of its higher capital costs, the longer schedule for implementation, and the potential reduction in habitat for endangered species that would be caused by the reduction in flow in Beaver Dam Creek. During the scoping period, DOE received no comments related to its preliminary determination of reasonable alternatives to be considered in the environmental impact statement.

Based on the screening process as documented in the Thermal Mitigation Study (DOE, 1984) and DOE's preliminary determination (50 FR 30728), DOE has decided to consider in detail in this environmental impact statement the alternatives of once-through and recirculating cooling towers for the K- and C-Reactors in addition to the "no-action" alternative (required by the Council on Environmental Quality for implementing the procedural provisions of the National Environmental Policy Act). For the D-Area coal-fired powerhouse, the Department has decided to consider in detail the alternatives of increased pumping to the raw water basin, direct discharge to the Savannah River, and "no action."

- AD-1 Since the completion of the Thermal Mitigation Study and the Draft EIS (DOE, 1986), further design evaluations and studies have been initiated to determine
- AD-2 optimal performance parameters and to achieve lower costs. These evaluations
- BB-1 and studies have indicated that, in several areas, optimization of performance
- BB-2 and cost savings can be realized in the construction and operation of once-
- BB-3 through towers without introducing major changes in the nature or magnitude of
- BB-4 the environmental impacts. These areas include the consideration of gravity-
- BC-4 feed versus pumped-feed towers, natural-draft versus mechanical-draft towers,
- BC-5 and a chemical injection system for either dissipation or neutralization of
- BC-6 chlorine biocide versus holding ponds (and their sizing). Similarly, these
- BC-14 evaluations and studies have also led to the development of thermal perform-
- BD-1 ance criteria that, when incorporated in the final design of a once-through
- cooling-tower system, would reduce the potential for cold shock (i.e., reduce
- the difference between ambient stream temperatures and stream temperatures
- when the cooling water is being discharged) to fish.

REFERENCES

DOE (U.S. Department of Energy), 1984. Thermal Mitigation Study, Compliance with Federal and South Carolina Water Quality Standards, Savannah River Plant, Aiken, South Carolina, DOE/SR-5003, Savannah River Operations Office, Aiken, South Carolina.

TC

DOE (U.S. Department of Energy), 1986. Draft Environmental Impact Statement, Alternative Cooling Water Systems, Savannah River Plant, Aiken, South Carolina, DOE/EIS-0121D, Savannah River Operations Office, Aiken, South Carolina.

APPENDIX B

THERMAL MODELING

B.1 INTRODUCTION

The thermal performance information presented in Sections 2.2, 2.3, and 2.4 of this environmental impact statement (EIS) was calculated with the aid of three models. The Cooling-Tower Performance (CTPERF) model computes effluent stream (water and air) temperatures as a function of influent stream properties and tower design. The Surface-water Heat, Savannah River Plant (SHSRP) model computes downstream temperatures along the SRP streams (Four Mile Creek, Pen Branch, Steel Creek, and Beaver Dam Creek) that receive cooling water effluent. The latter computation is performed as a function of effluent stream and extant meteorological properties. The Savannah River Dilution - D-Area (SRDD) model computes the temperature or dilution distribution in the Savannah River from D-Area based on discharge design and river flow.

In addition to a discussion of these three thermal performance models, this appendix also provides a brief description of the model (FOG) that has been used to calculate cooling system fogging, icing, visible plumes, and drift deposition.

B.2 COOLING-TOWER PERFORMANCE MODEL (CTPERF)

B.2.1 MODEL DESCRIPTION

The cooling of artificially heated water, such as the heated secondary cooling water at C- and K-Reactors, is a surface transport phenomenon between the water and the heat receptor (in this case the atmosphere). The cooling towers described in Chapter 2 of this EIS are efficient in this heat transfer because they maximize the exposed surface area of the water (via droplet formation) and introduce a heat sink (air) that does not contain residual heat from tower operation (due to the buoyancy of the heated air stream).

The heat-transfer process involves, chiefly, the transfer of latent heat due to the evaporation of a small portion of the water; a secondary cooling process is the transfer of heat due to the temperature difference between air and water. The theoretical limit to which the influent water temperature can be cooled is determined by the temperature and moisture content of the influent air stream. The wet-bulb temperature (t_{wb}), which is the temperature of saturated air at the same enthalpy (heat content) as the influent air, is an indication of the temperature and moisture content of the influent air and, as such, represents the theoretical limit to which the influent water temperature can be cooled. Practically, the cold-water temperature approaches, but does not equal, the wet-bulb temperature. The closeness of the approach depends on tower design parameters such as air-water contact time and droplet size (Perry, 1963).

The present analysis is based on the generally accepted Merkel equation (Perry, 1963).

$$\frac{KaV}{L} = \int_{t_2}^{t_1} \frac{dt}{h' - h} \quad (1)$$

where K = mass transfer coefficient, gm/hr/m²
 a = contact area, m²/m³ of tower volume
 V = active cooling volume, m³
 L = water flow rate, gm/hr
 h' = enthalpy of saturated air at the water temperature, cal/gm
 h = enthalpy of influent air stream, cal/gm
 t₁ = temperature of influent water stream, °C
 t₂ = temperature of effluent water stream, °C

Equation 1 expresses the mechanism of each droplet of water being surrounded by a film of air and the enthalpy difference between the film and surrounding air providing the driving force for the heat transfer. The left-hand side of Equation 1 is entirely in terms of tower-operating parameters, while the right-hand side is entirely in terms of air and water properties.

The latter characteristic of Equation 1 facilitates its use to compute tower performance. Tower design conditions (t₁, t₂, and t_{wb}) completely specify the value of the integral on the right-hand side of Equation 1. This value, called the tower characteristic, is dependent only on tower design parameters. Accordingly, t₂ can be obtained by implicitly solving Equation 1 for any given air wet-bulb temperature (t_{wb}), which defines h, hot-water temperature (t₁), and tower characteristic (determined, as described above, from design conditions). In addition, effluent air temperature is calculated by a heat balance approach; that is, the heat lost by the water in the tower is equated to the heat gained by the air.

As discussed above, the enthalpy difference h'-h is the driving force for cooling. The larger this difference, the more rapid the cooling of the water. Mathematically, the right-hand side of Equation 1 is the area under the $\frac{1}{h' - h}$ vs. t curve from t₂ to t₁.

At large values of t (i.e., close to t₁), the fraction $\frac{1}{h' - h}$ is very small.

As t decreases, the fraction correspondingly increases until, at t = t_{wb}, the fraction becomes infinite (the theoretical limit of cooling). This behavior of the integral can be related to the left-hand side of Equation 1, which indicates (for given flow rates) the tower characteristics. The cooling of the water from its initially high temperatures is very rapid and uses a small fraction of the tower. The cooling of the water at low temperatures is very slow and uses the major part of the tower. In terms of tower design, the size of the tower increases (approximately) exponentially for each increment of cooling desired.

The air flow rate is specified (constant) for the fan-driven mechanical draft tower. For the natural draft tower, the air flow rate is a function of the density difference between the incoming and outgoing air. The dry air flow rate can be derived by applying the Bernoulli equation and continuity to the tower inlet and outlet cross-sections. The result is:

$$G = A_2 U_2 \left(\frac{\rho_1}{1 + H_1} \right)$$

$$\text{where: } U_2^2 = \frac{U_2^2 = 2g_c y \left(\frac{\rho_1 - \rho_2}{\rho_2} \right)}{1 + k \frac{\rho_2 (A_2)^2}{\rho_1 (A_1)^2}}$$

g_c = 980 dynes/gm
 y = tower height, m
 ρ = density of air, gm/m³
 k = loss coefficient
 A = cross-section area, m²
 U = air velocity, m/sec
 H = absolute humidity, gm-water/gm-dry air
 G = dry air flow rate, gm/sec
 subscript 1 = tower inlet
 subscript 2 = tower outlet

3
 4
 BB-3
 BC-4
 BC-14
 BC-15
 15

CTPERF model results have shown excellent comparison with published tower design curves (Dickey and Cates, 1973).

B.2.2 MODEL USE

Table B-1 contains mean and maximum monthly wet bulb temperatures for the period 1952-1982 (Morris, 1987a). Tower effluent water temperatures, also given in Table B-1, are based on vendor supplied information. CTPERF was used to calculate performance equations relating effluent air temperatures and flow rates as a function of influent air wet bulb temperature and relative humidity.

BB-3
 BC-4

Once-through tower influent water temperatures, T_i , were based on monthly average reactor intake (Savannah River) temperatures (DOE, 1984a). These reactor intake temperatures were elevated by the temperature rise through the reactor heat exchangers, which can be described (Neill and Babcock, 1971; NUS Corporation, 1984) as

$$\Delta T = 65.79 - .6568 T_{in} \quad (2)$$

where ΔT = maximum reactor power secondary cooling water temperature rise
 across reactor heat exchangers, °C
 T_{in} = reactor intake temperature, °C

Adding T_{in} to Equation 2 yields

$$T_i = 65.79 + .3433 T_{in} \quad (3)$$

Table B-1. Monthly Average and Maximum Cooling-Tower Temperatures (°C)

Temperature	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Wet-bulb temperature												
Monthly average ^a	4	6	11	14	18	22	23	23	21	14	10	6
Monthly maximum ^b	20	20	21	24	25	26	27	27	26	25	23	21
Savannah River temperature												
Monthly average	8	8	11	15	18	21	23	23	22	19	15	11
Once-through tower effluent												
Temperature												
Monthly average	19	20	23	24	26	28	29	29	28	24	23	21
Monthly maximum	28	28	28	30	30	31	32	32	31	31	29	28
Recirculating tower effluent												
temperature												
Monthly average	14	15	18	20	23	26	27	26	25	20	18	15
Monthly maximum	25	25	26	28	28	29	30	30	29	28	27	26

^aBased on average dry bulb temperature and relative humidity.^bBased on maximum monthly dry bulb and coincident relative humidity.BB-3
BC-14
BC-15

Recirculating influent water temperatures are determined by imposing Equation 3 on the tower performance calculations. That is, rather than specifying the influent tower water temperature, T_1 , and calculating the effluent water temperature, T_2 , the calculation imposes the functional relationship

$$T_1 = 65.79 + .3433T_2 \quad (4)$$

onto the implicit cooling-tower calculations. Effluent natural draft water temperatures were used as influent water temperatures for the mechanical draft tower in the recirculating system.

BB-3
BC-4

B.2.3 MODEL RESULTS

The above information was used to calculate the effluent air performance equations for once-through (design conditions: $T_2 = 32.2^\circ\text{C}$, $T_{wb} = 27.8^\circ\text{C}$) and recirculating (natural draft design conditions: $T_2 = 38.1^\circ\text{C}$, $T_{wb} = 26.7^\circ\text{C}$; mechanical draft design conditions: $T_1 = 38.1^\circ\text{C}$, $T_2 = 29.4^\circ\text{C}$, $T_{wb} = 26.7^\circ\text{C}$) towers (Morris, 1987a). These results were used in simulating environmental effects (fogging, icing, aesthetics, deposition) from the effluent air stream (see Section B.5). Table B-1 includes the mean and maximum monthly effluent water temperature for each system type. The effluent water temperatures listed in Table B-1 are those included in the Chapter 2 thermal performance analyses.

BB-3
BC-4
BC-14
BC-15

The once-through towers are designed to meet State Class B water classification standards of a maximum instream temperature of 32.2°C at the point of discharge to the creeks. Table B-1 shows that the tower discharge will meet this requirement for all monthly maximum conditions.

The recirculating towers are also designed to meet State Class B water classification standards. However, because the effluent water also serves as influent water, this system has been designed to further lower the water temperature. A comparison of once-through and recirculating tower effluent temperatures in Table B-1 illustrates this difference.

B.3 SURFACE-WATER HEAT, SAVANNAH RIVER PLANT MODEL (SHSRP)

B.3.1 MODEL DESCRIPTION

As in the case of CTPERF, the cooling of artificially heated surface waters is a transport phenomenon between the water and the heat receptor (the atmosphere). Unlike the cooling towers, however, other processes contribute to this heat transfer.

The flux of heat across the water surface has various components that can be either positive (heat entering the water) or negative (heat exiting the water). The major processes are solar radiation, atmospheric radiation, back radiation from the water body, evaporation, and conduction.

The net solar heat flux, ϕ_{sn} , consists of incident solar radiation minus reflected solar radiation. The incident, clear-sky, solar radiation is a function of latitude, time of day, and time of year. In addition, reflection, scattering, and absorption by gases, water vapor, and particulates in the

atmosphere will affect this term. Accordingly, empirical representations are usually used to calculate the temporal distribution of incident solar radiation at a particular site. Reflected solar radiation from the water surface ranges from 5 to 10 percent of incident radiation (Thackston and Parker, 1971). A value of 6 percent was used in producing the baseline data for this study. The reduction of incident solar radiation by cloud cover is described by the factor $(1 - .65c^2)$ where c is the cloud cover (range of 0 to 1). The net temporal distribution of solar radiation used as the baseline for this study was produced by the UHSPOND code (Codell and Nuttle, 1980). The back radiation from the water surface is essentially "black body" radiation. The latter is described by the Stephan-Boltzmann law (Bird, Stewart, and Lightfoot, 1966):

$$\phi_b = \epsilon \sigma (T_s + 273)^4 \quad (5)$$

TE | where ϵ = atmospheric emissivity (1 for a theoretical black body)
 σ = Stephan-Boltzmann constant (1.17×10^{-6} Cal/m² - day
 - °K)
 $T_s + 273$ = absolute temperature of the water surface in °K

The emissivity of the water is well-known as 0.97 (Ryan and Stolzenbach, 1972). The long-wave atmospheric radiation, ϕ_a , is also described by Equation 5, except that the temperature used is that of the atmosphere, T_a . The emissivity of the atmosphere can be empirically described as

$$\epsilon = 9.4 \times 10^{-6} (T_a + 273)^2 (1 + .17c^2) \quad (6)$$

where the cloud-cover term describes the darkening of the sky and the attendant increase in emissivity. The net atmospheric radiation, ϕ_{an} , is taken as 97 percent (the water surface reflecting 3 percent) of the incident radiation (Ryan and Stolzenbach, 1972).

The evaporative heat flux, ϕ_e , from the water surface is mechanically equivalent to the latent heat of vaporization of the water being evaporated into an atmospheric boundary layer (which is in equilibrium with the water surface) and subsequently transported to the atmosphere. This transport (convection) of heat has two components: forced convection (due to the wind) and free convection (due to buoyancy effects).

The forced convection term, ϕ_{e1} , is empirically described as

$$\phi_{e1} = kW_2 (e_s - e_a) \quad (7)$$

TE | where k = a constant
 W_2 = the wind speed 2 meters above the water surface in meters per second
 e_s = the saturated vapor pressure at the temperature of the water surface in mm Hg
 e_a = the vapor pressure of the air (mm Hg)

The form of the free convection term, ϕ_{e2} , is taken from experimental work of free convection over a flat plate modified by the fact that water vapor is lighter than air (and, therefore, evaporation increases the buoyancy forces) (Ryan and Stolzenbach, 1972). The result is

$$\phi_{e2} = 18.4 (T_{sv} - T_{av})^{1/3} (e_s - e_a) \quad (8)$$

where $T_v = (T + 273)/(1 - .378e/p)$

$e = e_a$ and $T = T_a$ for $T_v = T_{av}$

$e = e_s$ and $T = T_s$ for $T_v = T_{sv}$

p = atmospheric pressure in mm Hg

TE

The total evaporative heat flux, ϕ_e , is then the sum of $\phi_{e1} + \phi_{e2}$.

A value of $k = 31.3$ (for the units given above) has been found to be appropriate (Ryan and Stolzenbach, 1972).

Previous studies have shown that the evaporative heat flux as calculated by Equations 7 and 8 is too large. A multiplicative constant, C , can be defined that results in a better approximation to the actual flux. A value of 0.78 has been found elsewhere (Firstenberg and Fisher, 1976) and is used here.

Heat conducted from the water to the atmosphere via the atmospheric boundary layer must be transported analogously to the convection of evaporative heat flux. The heat conduction flux, ϕ_c , is related to ϕ_e through the Bowen Ratio; that is

$$\phi_c / \phi_e = R(T_s - T_a) / (e_s - e_a) \quad (9)$$

where $R = .46 \text{ mm Hg}/^\circ\text{C}$ (Ryan and Stolzenbach, 1972).

The total heat flux, ϕ , into the water surface is then:

$$\phi = \phi_{sn} + \phi_{an} - \phi_b - \phi_e - \phi_c \quad (10)$$

Equation 10 allows the total heat flux to be calculated, given the solar radiation, air temperature, cloud cover, water temperature, wind speed, and relative humidity. For a given set of meteorological conditions, the only variable in this list is the water temperature, T_s . For the site streams, where the flow will be vertically well mixed (due to turbulent and shallow flow) and plug flow in character (due to the long, narrow nature of the streams and the assumed steady flow and meteorology), the equation describing the conservation of heat can be written as (Harleman, 1972)

$$\frac{UdT}{dx} = \frac{\phi}{\rho c d} \quad (11)$$

where U = average cross-section velocity, m/sec

T = water temperature, $^\circ\text{C}$

x = downstream distance, m

ρ = density of water, gm/m^3

c = specific heat of water, $\text{cal}/\text{gm}-^\circ\text{C}$

d = depth, m
 ϕ = total heat flux into the water surface, cal/m²-sec

Equation 11 quantitatively expresses that the change in heat content of the creek over a given distance (left-hand side of equation) is equal to the heat passing through the water surface over this distance (right-hand side of equation). For a given discharge and a given distance, all parameters in Equation 11 are known except for T and ϕ . Equation 11 together with Equation 10 allows the computation of T vs. x.

To facilitate the computation and illustrate the behavior of the solution, the concepts of surface-heat-exchange coefficient and equilibrium temperature are introduced. The surface-heat-exchange coefficient, K, relates the change in heat transfer rate to the change in water surface temperature (Edinger and Geyer, 1965):

$$K = \frac{-\partial\phi}{\partial T} \quad (12)$$

The equilibrium temperature, T_e , is the temperature that the water approaches for a given set of meteorological conditions (analogous to the wet-bulb temperature for cooling towers) and is that temperature at which $\phi = 0$ (calculated from Equation 10). Integrating Equation 12 and noting the definition of T_e yields:

$$\phi = -K (T - T_e) \quad (13)$$

which, when substituted in Equation 11, results in:

$$\frac{dT}{T - T_e} = \frac{-KW}{cQ} dx \quad (14)$$

where Q = flow rate, m³/sec
W = surface width, m
Q/W = Ud

Equation 14 can be integrated (for constants K, Q, W, and T_e) to give:

$$\frac{T_1 - T_e}{T_2 - T_e} = \exp \frac{KW}{\rho c Q} (x_2 - x_1) \quad (15)$$

where the subscript 1 indicates the inflow location and subscript 2 indicates the outflow location.

In typical applications (e.g., steam power plants) where the heat-exchange temperature rise is relatively small (e.g., 10°C), Equation 15 can be directly applied. However, for such applications as the highly elevated discharge temperatures from the existing C- and K-Reactor systems, the value of K cannot be considered constant over the large ranges of temperature, $T_1 - T_2$. This is illustrated in Figure B-1, which shows K vs. T for typical site summer meteorological conditions. [Analogous to the cooling-tower analysis, the rate of cooling at high temperatures (high K) is much more rapid than that at low temperatures (low K) due to the exponential relationship between K and

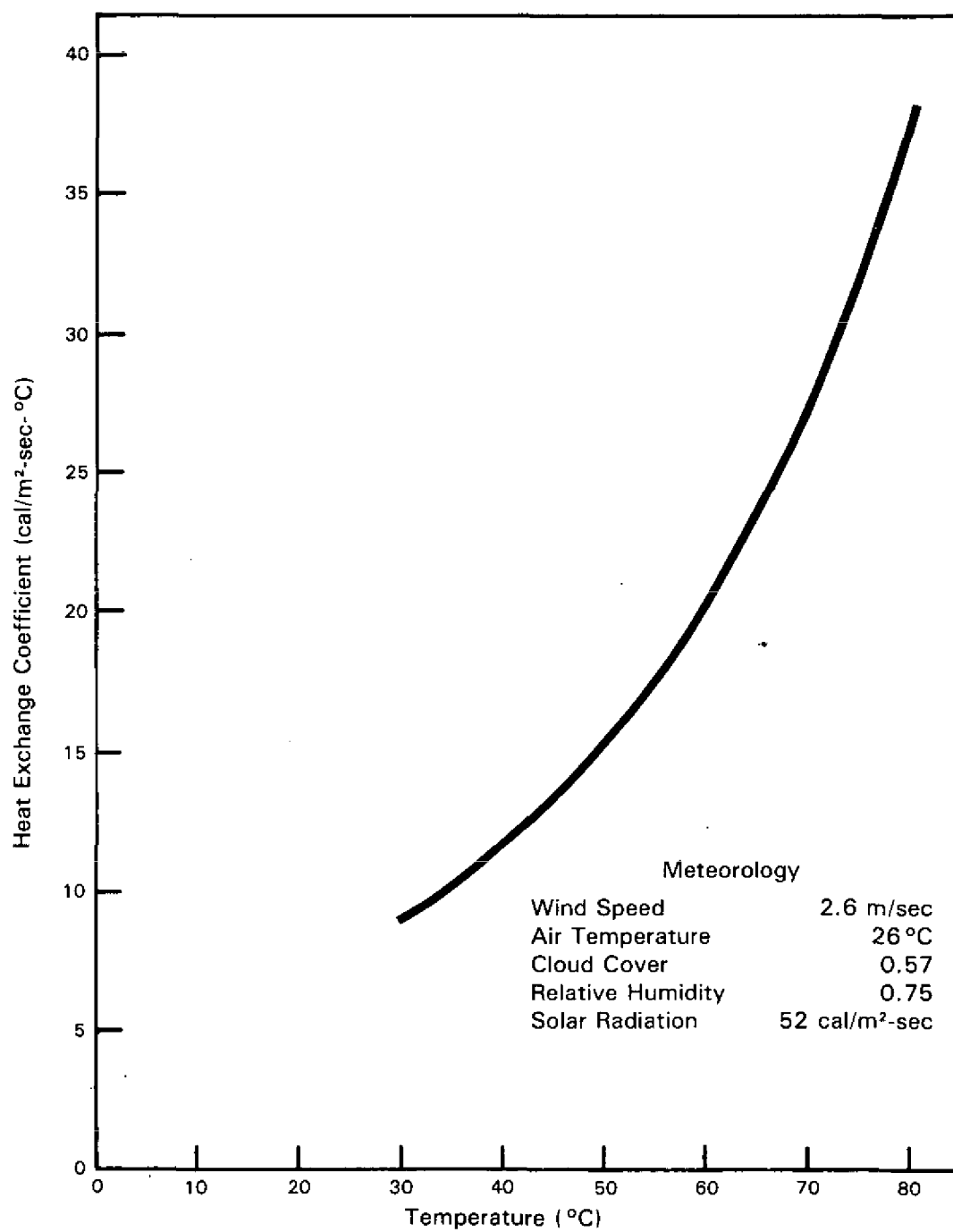


Figure B-1. Heat Exchange Coefficient vs Temperature (Typical Summer Conditions)

the water temperature]. Accordingly, SHSRP computes Equation 15 iteratively; that is, a series of small temperature steps, $T_1 - T_2$, are taken and the summation of the corresponding values of $x_2 - x_1$ is calculated. The process is repeated until the summation matches the required value.

SHSRP results have been compared with analytic solutions to the heat balance problem (Ryan, 1972). With the conditions for which analytic solutions are feasible (i.e., constant stream width), the two methodologies were in exact agreement. The results of SHSRP, with variable stream width, were also compared with temperatures measured in the thermally loaded SRP streams, Pen Branch and Four Mile Creek. Ground truth and remote sensing data for eight dates, which covered all seasons and a variety of operating modes, were used for the comparison. The Pearson product-moment correlation coefficients, which measure the linear relationship (or trend) between the measured and predicted temperatures, were found to be 0.93 and 0.86 for Pen Branch and Four Mile Creek, respectively. These coefficients indicate that SHSRP is a valuable tool in predicting SRP stream temperatures. The difference from a perfect correlation (coefficient = 1) could be explained by the error inherent in the measured temperatures, the uncertainty of the extant ambient flows, and the fact that the measurements are instantaneous, whereas the model uses daily average information.

B.3.2 MODEL USE

BC-4 SHSRP was used to calculate downstream temperature distributions during
BC-14 monthly average and extreme meteorological conditions for the various cooling-
BC-15 system alternatives for C- and K-Reactors and the D-Area powerhouse. Meteorological conditions (wind speed, air temperature, cloud cover, solar radiation, and relative humidity) were taken as those measured at Bush Field for the 30-year period 1953 to 1982 (NCDC, 1983). Table B-2 contains the minimum, mean, and maximum monthly average meteorological parameter values for the period of record.

BC-4 Equilibrium temperatures for daily average meteorological conditions were cal-
BC-14 culated for the 30-year period, and monthly averages of these values are given
BC-15 in Table B-2. Extreme monthly meteorological conditions were chosen as those extant during the months corresponding to the maximums in Table B-2. Average monthly meteorological conditions are the mean monthly averages given in the same table.

B.3.3 MODEL RESULTS

The above information was used to calculate the downstream temperatures in Four Mile Creek, Pen Branch, and Beaver Dam Creek during monthly average and extreme meteorological conditions. Downstream temperatures for the various alternatives and creeks, as illustrated in Figure B-2, are compiled in Tables B-3 through B-5.

BC-4 The tower discharge temperatures are based on the appropriate values from
BC-14 Table B-1. The once-through tower discharge flow rate is 11 cubic meters per
BC-15 second and the recirculating tower discharge (blowdown) flow rate is 0.7 cubic meter per second (Morris, 1987a). The annual average Four Mile Creek (at Road A-7) and Pen Branch (at Road B) flows, other than reactor effluent, are approximately 0.5 and 0.3 cubic meter per second, respectively, and are assumed to be at equilibrium temperature (Morris, 1987b).

Table B-2. Monthly Minimum, Mean, and Maximum Meteorological Parameters
Used in the Analysis of Downstream Temperatures

Parameter	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Wind speed, m/sec												
Minimum monthly average	2.3	2.9	3.2	2.6	2.3	2.1	2.1	2.1	1.9	1.9	2.0	2.3
Mean monthly average	3.2	3.5	3.6	3.4	2.9	2.8	2.6	2.5	2.5	2.6	2.8	3.0
Maximum monthly average	3.8	4.3	4.3	4.5	3.6	3.7	3.1	2.9	3.2	3.3	3.4	3.8
Air temperature, °C												
Minimum monthly average	2	4	7	14	19	23	24	24	20	15	9	4
Mean monthly average	7	8	12	17	21	25	26	26	23	17	12	8
Maximum monthly average	13	13	16	19	24	27	28	28	25	20	14	13
Cloud cover, fraction												
Minimum monthly average	.35	.27	.40	.36	.42	.37	.40	.32	.31	.16	.33	.46
Mean monthly average	.58	.54	.56	.50	.55	.56	.61	.54	.53	.42	.47	.54
Maximum monthly average	.73	.78	.73	.65	.77	.67	.80	.72	.71	.67	.61	.70
Solar radiation, cal/m ² -sec												
Minimum monthly average	21	27	34	43	43	48	40	41	36	30	27	20
Mean monthly average	26	34	41	51	53	56	53	52	44	40	31	25
Maximum monthly average	33	44	48	57	61	65	64	63	54	49	36	28
Relative humidity, fraction												
Minimum monthly average	.59	.53	.56	.60	.63	.61	.66	.68	.71	.64	.63	.62
Mean monthly average	.71	.67	.66	.66	.71	.72	.75	.76	.77	.74	.72	.72
Maximum monthly average	.82	.76	.73	.79	.79	.80	.82	.84	.83	.83	.77	.80
Equilibrium temperature, °C												
Minimum monthly average	3	7	10	18	23	27	28	27	23	17	11	5
Mean monthly average	8	10	15	21	25	28	30	29	26	20	13	9
Maximum monthly average	14	15	18	23	28	30	31	31	28	22	16	13

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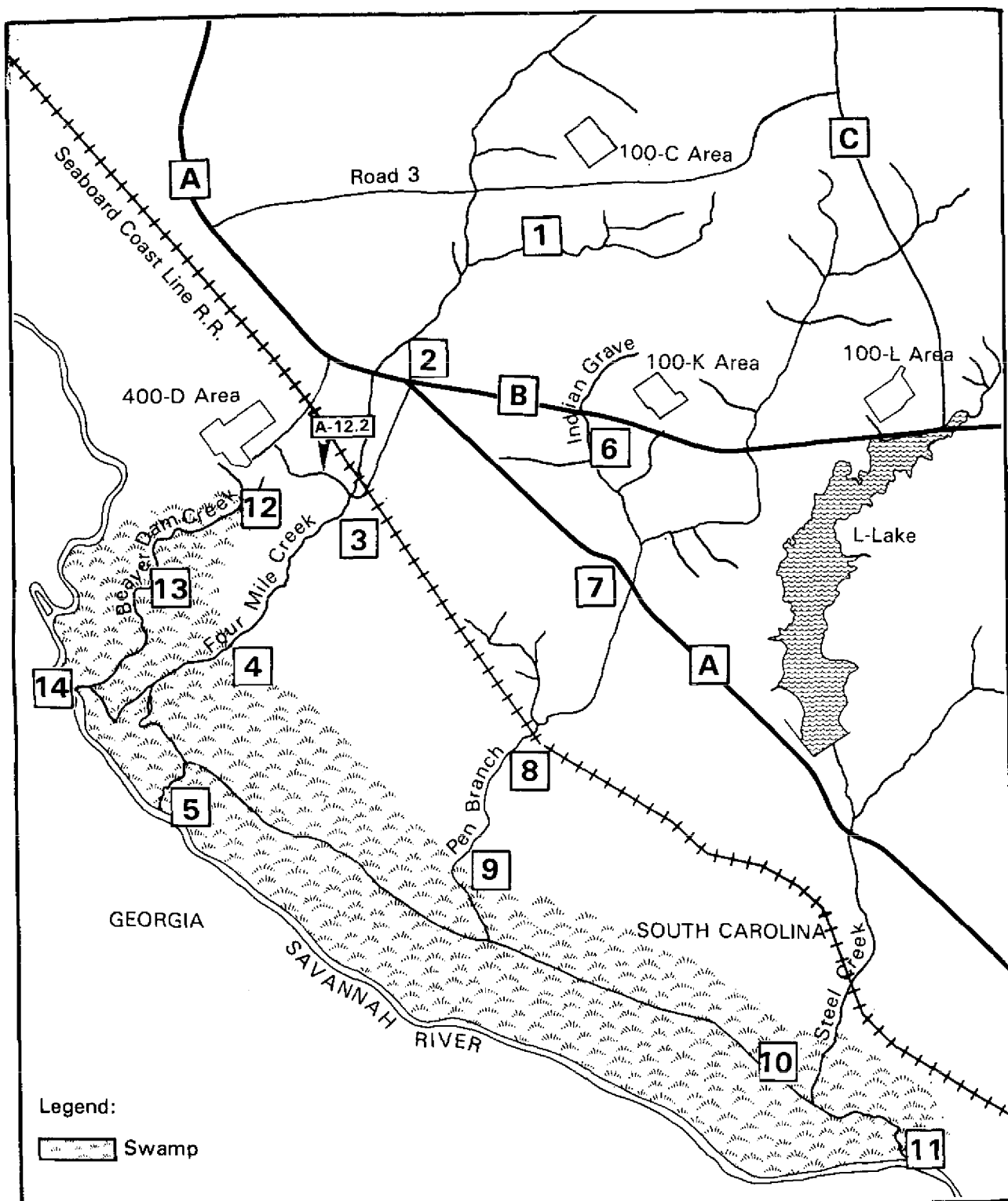


Figure B-2. Locations Corresponding to Downstream Temperatures in Tables B-3 through B-5

Table B-3. Downstream Temperature Distributions (°C) for Four Mile, Pen Branch, and Beaver Dam Creeks with Existing System^a

Location	Month											
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
C-Reactor												
(Four Mile Creek)												
Discharge (1) ^b	69(70)	69(71)	70(72)	71(73)	72(73)	73(74)	74(75)	74(75)	73(75)	72(74)	71(73)	70(72)
Road A (2)	49(51)	49(51)	50(52)	53(55)	55(57)	57(58)	57(58)	58(58)	57(58)	55(57)	52(53)	50(52)
Road A-13 (3)	42(45)	42(44)	44(45)	46(48)	49(51)	50(51)	51(52)	51(52)	50(51)	49(50)	45(47)	43(45)
Swamp Delta (4)	32(35)	33(35)	34(36)	38(39)	40(42)	42(43)	43(43)	43(44)	42(42)	39(40)	35(37)	33(35)
Mouth (5)	24(27)	24(27)	27(29)	30(32)	33(35)	35(36)	36(37)	36(37)	34(35)	31(33)	27(29)	25(27)
Ambient Creek ^c	9(19)	11(19)	15(24)	19(25)	22(27)	25(31)	25(29)	25(29)	23(28)	21(25)	13(23)	13(18)
K-Reactor												
(Pen Branch)												
Discharge (6)	69(70)	69(71)	70(72)	71(73)	72(73)	73(74)	74(75)	74(75)	73(75)	72(74)	71(73)	70(72)
Road A (7)	61(63)	60(62)	61(63)	63(65)	66(67)	67(68)	68(69)	68(69)	68(69)	67(68)	64(66)	62(64)
RR Bridge (8)	52(54)	51(53)	52(54)	55(56)	57(59)	59(60)	59(60)	60(60)	59(60)	58(59)	54(56)	53(55)
Swamp Delta (9)	42(44)	42(44)	43(44)	46(48)	48(50)	50(51)	51(51)	51(51)	50(51)	48(49)	45(46)	43(45)
Above Steel Creek (10)	16(21)	17(21)	20(22)	24(26)	27(29)	29(30)	30(31)	30(31)	28(29)	24(26)	20(22)	17(20)
Mouth (11)	13(17)	15(18)	18(21)	21(23)	24(27)	27(28)	28(29)	28(29)	26(27)	22(24)	17(19)	14(17)
Ambient Creek ^d	8(18)	10(18)	15(22)	18(23)	21(24)	23(27)	23(27)	23(26)	21(26)	19(23)	13(21)	12(17)
D-Area												
(Beaver Dam Creek)												
Discharge (12)	18(27)	16(22)	21(27)	24(29)	28(32)	29(34)	28(33)	28(33)	27(33)	27(34)	26(33)	19(31)
Swamp Delta (13)	17(25)	16(21)	20(26)	24(28)	27(31)	28(33)	28(33)	28(32)	27(32)	26(32)	24(30)	18(28)
Mouth (14)	17(22)	17(21)	20(24)	24(27)	27(29)	29(31)	30(31)	29(31)	28(30)	25(29)	22(27)	18(23)
Ambient creek ^e	8(15)	9(14)	12(17)	15(20)	19(22)	21(25)	23(27)	23(26)	23(26)	20(23)	17(22)	12(18)

a. Temperatures are monthly average - monthly extremes are in parentheses.

b. Corresponds to stream locations shown as squares on Figure B-2.

c. U.S. Geological Survey data for water year 1985 for station 02197342; Four Mile Creek at Road A-7 (USGS, 1986).

d. U.S. Geological Survey data for water year 1985 for station 02197341; Pen Branch at Road B (USGS, 1986).

e. Average U.S. Geological Survey data for water years 1976-1985 for station 01297320; Savannah River near Jackson, S.C. (USGS; 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986).

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Table B-4. Downstream Temperature Distributions (°C) for Four Mile, Pen Branch, and Beaver Dam Creeks with Once-Through Towers for Each Reactor and for the Increased Pumping Alternative for D-Area^a

Location	Month											
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
C-Reactor												
(Four Mile Creek)												
Discharge (1) ^b	19(28)	20(28)	23(28)	24(30)	26(30)	28(31)	29(32)	29(32)	28(31)	24(31)	23(29)	21(28)
Road A (2)	18(26)	18(26)	21(26)	23(28)	25(29)	28(30)	29(31)	29(31)	27(30)	23(29)	21(27)	19(26)
Road A-13 (3)	17(24)	17(24)	21(25)	23(28)	25(29)	28(30)	29(31)	28(31)	27(30)	23(28)	20(26)	18(25)
Swamp Delta (4)	15(22)	16(22)	19(23)	22(26)	25(28)	27(30)	28(30)	28(30)	26(29)	22(26)	19(24)	16(22)
Mouth (5)	13(20)	14(20)	18(21)	20(24)	23(27)	26(28)	27(29)	27(29)	25(27)	20(24)	17(21)	14(19)
Ambient Creek ^c	9(19)	11(19)	15(24)	19(25)	22(27)	25(31)	25(29)	25(29)	23(28)	21(25)	13(23)	13(18)
K-Reactor												
(Pen Branch)												
Discharge (6)	19(28)	20(28)	23(28)	24(30)	26(30)	28(31)	29(32)	29(32)	28(31)	24(31)	23(29)	21(28)
Road A (7)	18(27)	19(27)	22(27)	24(29)	26(30)	28(31)	29(32)	29(32)	28(31)	24(30)	22(28)	20(27)
RR Bridge (8)	18(26)	18(26)	21(26)	23(29)	26(30)	28(31)	29(31)	29(31)	28(30)	24(29)	21(27)	19(26)
Swamp Delta (9)	16(24)	17(24)	20(25)	23(27)	25(29)	28(30)	29(31)	28(31)	27(30)	23(28)	20(26)	18(24)
Above Steel												
Creek (10)	10(17)	12(17)	16(19)	18(21)	21(24)	24(26)	26(27)	25(27)	23(24)	18(21)	15(18)	11(16)
Mouth (11)	10(15)	12(16)	16(19)	18(20)	21(24)	24(26)	25(27)	25(26)	22(24)	17(21)	15(17)	11(15)
Ambient Creek ^d	8(18)	10(18)	15(22)	18(23)	21(24)	23(27)	23(27)	23(26)	21(26)	19(23)	13(21)	12(17)
D-Area^e												
(Beaver Dam Creek)												
Discharge (12)	18(27)	16(22)	21(27)	24(29)	28(30)	29(32)	28(30)	28(31)	27(31)	27(32)	26(31)	19(31)
Swamp Delta (13)	17(25)	16(21)	20(26)	24(28)	27(30)	28(31)	28(30)	28(31)	27(30)	26(31)	24(29)	18(28)
Mouth (14)	13(20)	14(19)	17(21)	20(24)	24(27)	26(29)	27(29)	27(29)	25(27)	21(26)	19(23)	14(21)
Ambient creek ^f	8(15)	9(14)	12(17)	15(20)	19(22)	21(25)	23(27)	23(26)	23(26)	20(23)	17(22)	12(18)

a. Temperatures are monthly average - monthly extremes are in parentheses.

b. Corresponds to stream locations shown as squares on Figure B-2.

c. U.S. Geological Survey data for water year 1985 for station 02197342; Four Mile Creek at Road A-7 (USGS, 1986).

d. U.S. Geological Survey data for water year 1985 for station 02197341; Pen Branch at Road B (USGS, 1986).

e. Increased pumping alternative for D-Area. This alternative is equivalent to existing system for average conditions.

f. Average U.S. Geological Survey data for water years 1976-1985 for station 01297320; Savannah River near Jackson, S.C. (USGS; 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986).

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BC-15

Table B-5. Downstream Temperature Distributions (°C) for Four Mile, Pen Branch, and Beaver Dam Creeks with Recirculating Towers for Each Reactor and for the Increased Pumping Alternative for D-Area^a

Location	Month											
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
C-Reactor												
(Four Mile Creek)												
Discharge (1) ^b	14(25)	15(25)	18(26)	20(28)	23(28)	26(29)	27(30)	26(30)	25(29)	20(28)	18(27)	15(26)
Road A (2)	9(16)	11(16)	15(18)	18(21)	22(25)	25(27)	27(28)	26(28)	23(25)	17(21)	14(18)	10(15)
Road A-13 (3)	8(15)	11(16)	15(18)	18(21)	22(25)	25(28)	27(29)	26(28)	23(25)	17(21)	14(17)	9(15)
Swamp Delta (4)	8(15)	10(15)	14(17)	19(21)	22(26)	26(28)	27(29)	27(29)	24(26)	17(20)	13(16)	9(14)
Mouth (5)	7(14)	10(14)	14(17)	17(19)	20(23)	24(25)	25(26)	25(25)	21(23)	15(19)	13(15)	8(13)
Ambient Creek ^c	9(19)	11(19)	15(24)	19(25)	22(27)	25(31)	25(29)	25(29)	23(28)	21(25)	13(23)	13(18)
K-Reactor												
(Pen Branch)												
Discharge (6)	14(25)	15(25)	18(26)	20(28)	23(28)	26(29)	27(30)	26(30)	25(29)	20(28)	18(27)	15(26)
Road A (7)	11(19)	12(18)	16(20)	19(24)	23(27)	26(28)	27(29)	27(29)	24(27)	19(25)	15(21)	12(19)
RR Bridge (8)	9(17)	11(17)	15(19)	19(23)	23(26)	26(28)	27(29)	27(29)	24(27)	18(23)	15(19)	11(17)
Swamp Delta (9)	8(15)	11(16)	15(18)	19(22)	23(26)	26(28)	28(29)	27(29)	24(26)	17(21)	14(17)	9(15)
Above Steel Creek (10)	7(14)	10(14)	14(16)	15(17)	17(20)	21(23)	23(24)	22(23)	18(19)	13(17)	12(15)	8(12)
Mouth (11)	10(14)	11(15)	15(19)	18(20)	21(24)	25(26)	25(27)	23(24)	20(23)	13(19)	15(17)	11(14)
Ambient Creek ^d	8(18)	10(18)	15(22)	18(23)	21(24)	23(27)	23(27)	23(26)	21(26)	19(23)	13(21)	12(17)
D-Area^e												
(Beaver Dam Creek)												
Discharge (12)	18(27)	16(22)	21(27)	24(29)	28(30)	29(32)	28(30)	28(31)	27(31)	27(32)	26(31)	19(31)
Swamp Delta (13)	17(25)	16(21)	20(26)	24(28)	27(30)	28(31)	28(30)	28(31)	27(30)	26(31)	24(29)	18(28)
Mouth (14)	15(22)	15(19)	18(23)	22(26)	26(28)	27(30)	27(29)	27(30)	26(29)	24(28)	22(26)	16(24)
Ambient creek ^f	8(15)	9(14)	12(17)	15(20)	19(22)	21(25)	23(27)	23(26)	23(26)	20(23)	17(22)	12(18)

a. Temperatures are monthly average - monthly extremes are in parentheses.

b. Corresponds to stream locations shown as squares on Figure B-2.

c. U.S. Geological Survey data for water year 1985 for station 02197342; Four Mile Creek at Road A-7 (USGS, 1986).

d. U.S. Geological Survey data for water year 1985 for station 02197341; Pen Branch at Road B (USGS, 1986).

e. Increased pumping alternative for D-Area. This alternative is equivalent to existing system for average conditions.

f. Average U.S. Geological Survey data for water years 1976-1985 for station 01297320; Savannah River near Jackson, S.C. (USGS; 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986).

BC-4
BC-14
BC-15

The existing system discharge flow is approximately 11 cubic meters per second and consists of heat exchanger effluent (at Savannah River temperature raised according to equation 2 of Section B.2.2) plus auxiliary flow (assumed to be at Savannah River temperature). The D-Area discharge flow is about 2.6 cubic meters per second (up to 4.0 cubic meters per second during extreme conditions for the increased pumping alternative); its temperature is equal to the Savannah River temperature plus 8°C (plus 5°C during maximum flow conditions for the increased pumping alternative).

Tables B-3 and B-4 indicate the large, incremental change in stream temperatures from the existing system to the once-through towers. A further decrease in stream temperatures (as well as a large decrease in stream flow) occurs when recirculating towers are used (Table B-5). Downstream temperatures can increase when recirculating systems are used because the equilibrium temperatures (which the stream temperatures approach) are higher than those of the discharge while the flow is small. Downstream temperatures can increase because of both positive heat flux (into the water surface) and mixing with creek flow (other than reactor effluent).

BC-4
BC-14
BC-15

The heat balance, and therefore the equilibrium temperature, takes into account spatial and temporal variations in vegetative cover of the streams. Four Mile Creek and Pen Branch were broken down into three spatial regimes [upper reach, middle reach, and lower (swamp) reach]; Beaver Dam Creek was considered to consist of an upper and lower reach. The percent of vegetative shading was defined for each month of the year for each reach (Morris, 1987b). Values ranged from less than 10 percent in the winter (all reaches) to 90 percent in the swamp during the summer.

B.4 SAVANNAH RIVER DILUTION - D-AREA MODEL (SRDD)

B.4.1 MODEL DESCRIPTION

The dispersion of a source of water with a temperature (or concentration) elevated above that of the receiving water can be thought of as occurring in two steps. The "near field" is the area in the immediate vicinity of the discharge in which the mechanical mixing engendered by the difference in discharge and receiving water momentum dominates the dispersion process. After the discharge momentum has dissipated, the "far field" mechanism of receiving water turbulence causing mixing of the discharge and receiving waters is dominant. If the discharge momentum is relatively small (i.e., discharge velocity approximately equal to receiving water velocity), the near field can be (conservatively) neglected.

The far field dispersion of a steady nondecaying point source discharge into a current of velocity, u , can be described by (NRC, 1977):

TC

$$\frac{\partial uC}{\partial x} = \frac{\partial}{\partial y} K_y \frac{\partial C}{\partial y} + \frac{K_z}{\partial z} \frac{\partial C}{\partial z} \quad (16)$$

where C = temperature or concentration excess above ambient
 u = ambient velocity, m/sec
 x = downstream distance, m
 y = lateral distance (i.e., perpendicular to current), m
 z = depth, m
 K_y, K_z = lateral and vertical diffusion coefficient, m^2/sec

Longitudinal diffusion is assumed to be negligible when compared with advection in the same direction. Also, temperature can be considered to be a non-decaying (i.e., no heat transfer to the atmosphere) source within the region of interest because the affected areas are small. In any case, omission of surface heat transfer is a conservative assumption.

Equation 16 states that the excess concentration is moved downstream by advection (movement by the current, left side of Equation 16) and laterally and vertically in the direction of decreasing concentration by turbulence (first and second term on right side of Equation 16, respectively). If u, K_y , and K_z are taken to be constants, then Equation 16 becomes:

$$u \frac{\partial C}{\partial x} = K_y \frac{\partial^2 C}{\partial y^2} + K_z \frac{\partial^2 C}{\partial z^2} \quad (17)$$

For an infinite receiving water, laterally and vertically surrounding the discharge point, the analytical solution to Equation 17 is:

$$\frac{C}{C_0} = \frac{Q}{4\pi \times \sqrt{K_y K_z}} \exp \left[\frac{-u(y_s - y)^2}{4K_y x} \right] \exp \left[\frac{-u(z_s - z)^2}{4K_z x} \right] \quad (18)$$

where C_0 = excess temperature (or concentration) of the discharge
 Q = discharge flow, m^3/sec
 y_s = lateral distance of source from coordinate origin
 z_s = vertical distance of source from coordinate origin

and the discharge is assumed at $x = 0$.

The Gaussian distribution of Equation 18 can be generalized for a receiving water of finite dimensions by adding images of the concentration distribution, Equation 18, from the bounding surfaces; that is, the infinite distribution of Equation 18 can be "folded" back into the water body at the boundaries, with the folded excess concentrations each being a component of the total excess concentrations. One can picture an infinite number of folds (e.g., the left-hand side of the lateral distribution would be folded at the left boundary; the resulting distribution would then laterally exceed the right boundary and would have to be folded there, etc.) for each side (of the source) for both the lateral (shorelines) and vertical (surface and bottom) directions (i.e., four infinite series). The mathematical description of these images or folds is (NRC, 1977):

$$\frac{C}{C_0} = \frac{Q}{4\pi \times \sqrt{K_y K_z}} f(y) f(z) \quad (19)$$

where:

$$f(w) = \sum_{m=-\infty}^{\infty} \exp \left[\frac{-u(2mW + w_s - w)^2}{4 K_w x} \right] + \sum_{m=-\infty}^{\infty} \exp \left[\frac{-u(2mW - w_s - w)^2}{4 K_w x} \right]$$

and $w = y$ or z

$W = B$ (receiving water width) if $w = y$ or D (receiving water depth) if $w = z$

Note that $f(y)$ and $f(z)$ describe the infinite folds of the first and second exponential terms, respectively, of Equation 18.

A further refinement of the analysis stems from the assumption of a point source discharge. Equation 19 can be generalized to account for an arbitrary discharge geometry by integrating over the discharge dimensions (i.e., consider the discharge an infinite number of point sources), where Q would then be the discharge flow per unit discharge size (i.e., length for a line source or area for a plane source). Such an integration of Equation 19 would have to be performed numerically and would be very time-consuming, computationally. Accordingly, an analytical approximation to this integration has been used.

The areal nature of the discharge source is accounted for by taking a virtual source distance x_v ; x_v corresponds to the distance, x , at which (for $y = y_s$ and $z = z_s$) C/C_o equals 1 in Equation 19. Accordingly, Equation 19 is modified by replacing x with $x + x_v$. The use of a virtual source distance assures conservation of mass, avoids the mathematical singularity at $x = 0$, and ensures that the calculated concentration (or temperature) at the source is equal to that being discharged.

B.4.2 MODEL USE

The model described in Section B.4.1 was generalized for use in calculating the temperature distribution in the Savannah River from the multiple-source D-Area sparge discharge system. Based on preliminary design assumptions, the system would consist of approximately 65 discharge pipes, 20 centimeters in diameter and 9 meters long, spaced at 3-meter intervals and aligned along the river bank. SRDD models such a system by considering each of the discharge pipes as a component to the overall temperature (or concentration) distribution. Distances x are measured, for each pipe, from that pipe ($x = 0$ is taken at the upstream pipe). Virtual source distances, x_v , are calculated individually for each pipe (i.e., C/C_o equals 1 at each pipe, accounting for the contributions of all upstream sources).

The total discharge flow is 2.6 cubic meters per second, 0.04 cubic meter per second per discharge pipe; the discharge water velocity is 1.2 meters per second, and its excess temperature is 8°C (above the temperature of the river). Table B-6 lists the Savannah River parameters used in the analysis. The approximate river cross-section at the discharge (average width = 61 meters, average depth = 3.2 meters) was known for a base river flow of 188 cubic meters per second. Log-log interpolations of river gage heights at Jackson for this flow (gage height = 2.28) and for 490 cubic meters per second [gage height = 4.62 meters (USGS, 1981)] were performed for the seasonal

Table B-6. Savannah River Parameters Used in Analysis

Parameter	Winter average	Spring average	Summer average	Summer extreme
Flow (m ³ /sec)	345.0	371.0	212.0	159.0
Width (m)	70.0	71.0	65.0	59.0
Depth (m)	4.6	4.8	3.5	2.9
Temperature (°C)	8.0	17.0	23.0	28.0
Horizontal diffusion coefficient (m ² /sec)	.26	.26	.26	.26
Vertical diffusion coefficient (m ² /sec)	.0026	.0026	.0026	.0026

flows. The change in gage height between the interpolated value and that at the base flow was assumed to be the change in average depth at the discharge. Typically, as the flow increases, the width, depth, and velocity of the river increases. Average widths were assumed to be the mean of 61 meters (known width at the base flow) and that width that would result in the same average river velocity as that at the base flow. These assumptions will result in river dimensions that accede to the typical river dimension-flow characteristics described above.

For the region near the discharge (about 100 meters from the discharge), the temperature distribution will be (for a given velocity) insensitive to the river dimensions. This occurs because the plume has not had time to grow sufficiently such that the images from the far boundaries (Georgia shoreline and river bottom) are important. In addition, the temperature at any given coordinate decreases with increasing river velocity. This is apparent from Equation 19, which shows that the river velocity, u , enters the temperature function as $\exp(-u)$.

The chosen horizontal diffusion coefficient is based on studies of the Savannah River approximately 20 kilometers downstream (Steel Creek) from the discharge (Du Pont, 1981, Appendix A). The vertical diffusion coefficient is typically one to two orders of magnitude smaller than the horizontal diffusion coefficient (NRC, 1977; Yotsukura and Sayre, 1976; Fischer, 1969). Calculations with $K_z = 0.0026$ and 0.026 square meter per second indicate that the former yields larger values of maximum isotherm width and cross-sectional area. However, at distances farther downstream than considered here, the discharge will be fully mixed vertically and the distribution will be independent of K_z . $K_z = 0.0026$ square meter per second was used in the analysis.

B.4.3 MODEL RESULTS

Table B-7 lists the river withdrawal and discharge temperatures along with the zones of passage for each seasonal case. The discharge temperatures for this alternative, unlike the others, are based on elevating measured Savannah River temperatures (rather than being measured discharge temperatures). This is

BC-4
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BC-15

Table B-7. Temperatures and Zone of Passage Sizes for D-Area Coal-fired Powerhouse Direct Discharge into Savannah River

Parameter	Winter average	Spring average	Summer average	Summer extreme
Temperature (°C)				
Withdrawal from river	8.0	17.0	23.0	28.0
Discharge	16.0	25.0	31.0	36.0
Maximum river cross-sectional area (percent of total) having temperature (°C) less than				
2.8 (excess)	99.7	99.7	99.5	99.3
32.2 (absolute)	100	100	100	99.7
Maximum river width (percent of total) having temperature excess (°C) less than				
2.8 (excess)	95	95	94	93
32.2 (absolute)	100	100	100	96

BC-4 | because comparison between river and discharge are relevant and need to be on
BC-14 | the same basis. The extreme summer conditions result in the smallest zones of
BC-15 | passage. Figure B-3 shows the maximum cross-sectional area (as a fraction of
the total), and downstream extent (meters from the discharge pipe farthest
upstream) as a function of excess temperature for extreme summer conditions.
Excess temperatures corresponding to those extents less than 3 meters down-
stream from the discharge pipe located farthest downstream will actually exist
intermittently in the river; that is, such isopleths (greater than 2.8°C)
exist near each discharge pipe but will dissipate between pipes.

Figure B-3 also shows the suggested width and cross-sectional area of the zone of passage. This figure shows that the direct discharge will be well within the suggested zone-of-passage criteria.

B.5 FOG MODEL

The occurrences of ground-level fogging, icing, elevated visible plumes, and ground deposition rates of dissolved solids in drift in the environmental impact statement were calculated by the NUS computer code FOG (Fisher, 1974). The FOG model provides predictions of these environmental impacts over a geographical area surrounding the site. For these analyses, sequential hourly meteorological data representative of the geographical areas surrounding C-Area and K-Area at the Savannah River Plant were used for the 5-year period from January 1975 to October 1979.

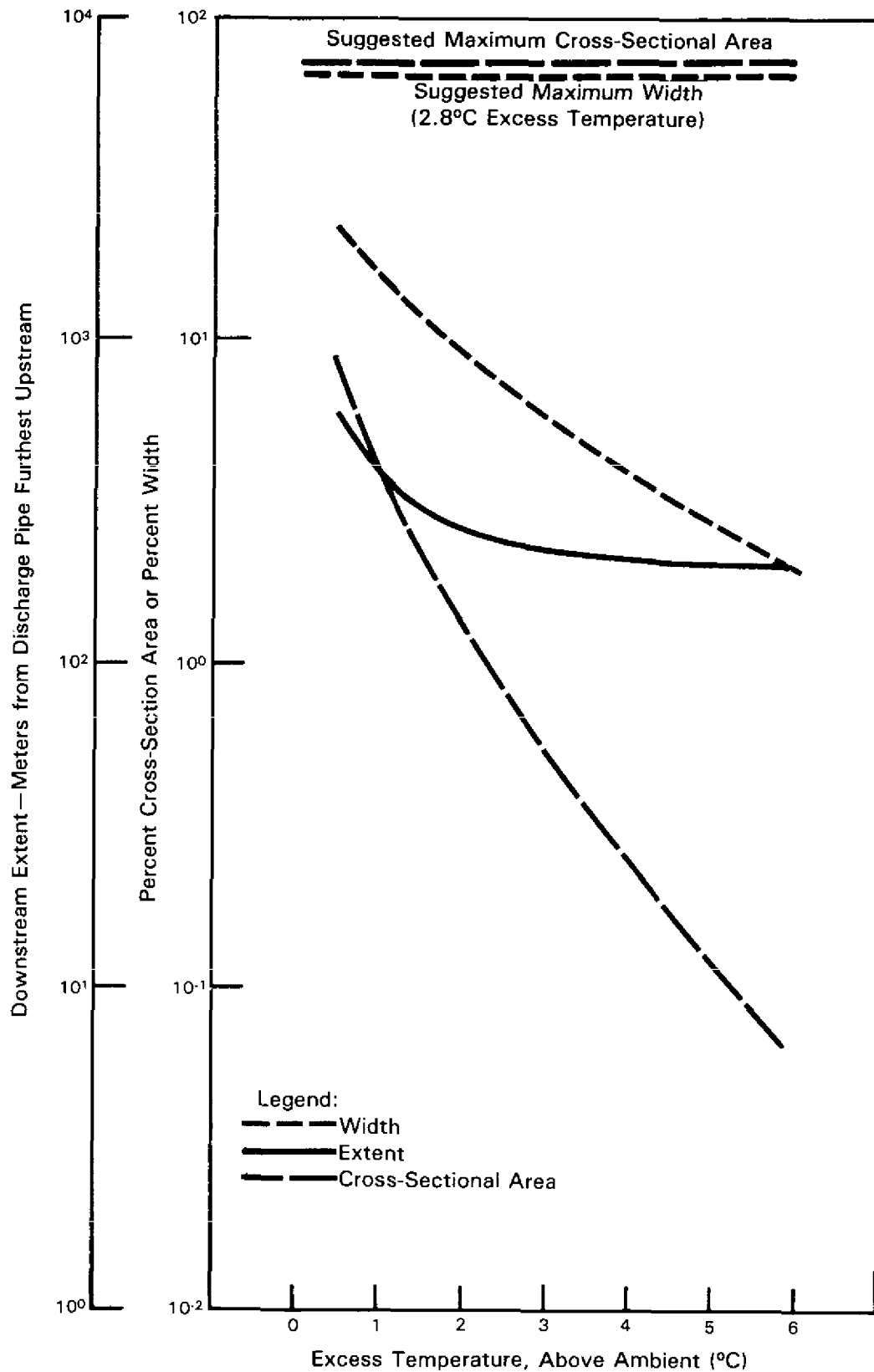


Figure B-3. Extreme Summer Plume Characteristics

The FOG model simulates the dispersion of a plume from evaporative cooling systems using sequential meteorological data. It defines a bent-over plume using the Briggs plume rise equations (Briggs, 1969) out to the distance at which the plume levels off, and Gaussian dispersion equations at greater distances. The plume buoyancy employed in the calculations is computed from the effluent temperature and airflow rate at the exit of the cooling tower and from the ambient dry-bulb temperature and relative humidity. The merging of plumes from the round, mechanical-draft, multifan cooling towers is considered using equations developed by Briggs (1974) for a cluster of cells.

The plume is assumed to propagate rectilinearly, and any meandering effects due to wind shifts are neglected. Atmospheric stability classes are those calculated from the standard deviation of wind direction fluctuations or, if these data are unavailable, from those reported by the National Weather Service for every hour for the period under consideration. The dispersion parameters used were those of Pasquill-Gifford (DOE, 1984c). Formulations for critical wind speed relative to the aerodynamic downwash of the exhaust plumes, in the wake of the tower under high wind conditions, are also included in the FOG model.

In addition to the preliminary design information contained in Chapter 2, the following assumptions were made in the analysis of fogging, icing, visible plumes, and ground deposition rates of dissolved solids:

- Circulating water flow = 11.3 cubic meters per second
- Drift rate (percent of circulating water flow) = 0.006 percent
- Total dissolved solids concentrations (TDS) in influent water = 53 parts per million
- Cycles of concentration for recirculating towers = 3
- Drift droplet size (mass median diameter) = 376 microns
- Air flow rate for mechanical draft recirculating tower = 13,848 cubic meters per second

B.5.1 INDUCED GROUND-LEVEL FOGGING

For the purposes of these analyses, induced ground-level fog is defined as a reduction in ground-level visibility to 1000 meters or less as a result of the operation of the cooling system. Huschke (1959) defines the 1000-meter distance as the limit on visibility above which fog is not considered to occur. The water content of the plume at ground level is calculated by means of the Gaussian dispersion analysis discussed above; all moisture in excess of that required to saturate the ambient air is assumed to form condensed water droplets. An empirical equation (Pettersen, 1956) is then used to relate the atmospheric water content to the horizontal visibility.

B.5.2 INDUCED GROUND-LEVEL ICING

The frequencies of occurrence of various ice thicknesses resulting from the operation of the cooling towers were also calculated by FOG code subroutines that simulate the formation and accumulation of ice and calculate the frequencies of ice occurrences.

The ice-formation routines predict accumulations of ice around a cooling system from the impingement of condensed water and drift droplets. Calculations

of ice buildup are made for horizontal flat surfaces (e.g., roads). The rate of ice buildup can be limited either by the liquid water delivery rate to the collecting surface or by the heat balance necessary to sustain freezing conditions.

The dispersion of the relatively small condensed water droplets is treated the same as that of the vapor plume (i.e., by diffusion), while the transport of the drift droplets follows the ballistic trajectory method employed for the salt deposition calculations. The FOG model performs an energy balance on the surface or volume of interest. Ice formation is assumed to occur only when the ambient temperature is less than 0°C. Ice buildup on horizontal ground-level surfaces is assumed to result only from fallout of the drift droplets. Because the much smaller condensed water droplets have negligibly small settling velocities, the condensed water droplets are assumed not to impinge on flat horizontal surfaces. Melting due to solar radiation is included in the simulation for flat surfaces.

B.5.3 ELEVATED VISIBLE PLUMES

The FOG code was also used to calculate the frequencies of occurrence of elevated visible plumes over each grid point under consideration. The total flux of air through a cross-section of the plume normal to the plume axis is calculated at successive downwind distances. The amount of entrained air is computed as the difference between the total air flow and the air flow leaving the cooling system. The entrained air and effluent air from the cooling system are assumed to be thoroughly mixed isobarically and thermodynamic properties of the resulting mixture are calculated. A visible plume is predicted to occur at a particular point if calculations show that the mixed plume is supersaturated.

B.5.4 DRIFT DEPOSITION

Drift deposition analysis by the FOG code involves the following three calculations: (1) the sequential release of the entrained drift droplets from the effluent plume; (2) the subsequent horizontal transport of the drift droplets; and (3) the deposition rates at prespecified downwind distances for each wind direction.

It is assumed in the FOG model that the initial concentration of drift droplets follows a Gaussian distribution normal to the plume axis. The release of the entrained droplets at any point within the plume depends on the relative magnitudes of the terminal fall velocity of the droplets and the vertical velocity of the air in the plume. At each downwind distance under consideration, these two velocities are compared for each of the various size categories of drift droplets, and a fraction of the droplets released. This process is repeated until all drift droplets are released from the plume. This drift is carried by the ambient wind until it is deposited on the ground. The rate of fall of the drift droplets depends on the droplet size, which is changed by evaporation processes. These, in turn, depend on the physical and transport properties of both the liquid droplets and the surrounding air. A stepwise procedure is employed in the FOG code to compute the trajectory of the droplets by considering these transport, evaporation, and settling rate effects.

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APPENDIX C

ECOLOGY

C.1 INTRODUCTION

This appendix is based primarily on information from three documents: the Comprehensive Cooling Water Study (Du Pont, 1985, 1987), which presents data collected in 1982 and additional data collected through August 1985; a report that summarizes impingement and entrainment impacts at the SRP from 1983-1985 (DOE, 1987); and a report on studies conducted at the site to evaluate the potential effects of chlorination and dechlorination activities related to proposed cooling towers for K- and C-Reactors (Wilde, 1987).

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BD-5

In 1972, the Savannah River Plant became a National Environmental Research Park. The Plant has one of the most intensively studied environments in the country. More than 700 scientific publications have resulted principally from research efforts by three organizations at the Plant: the Savannah River Laboratory, the Savannah River Ecology Laboratory, and the U.S. Forest Service (Wiener and Smith, 1981). Other research efforts include (1) surveys of the aquatic ecology of the Savannah River since 1951 by the Academy of Natural Sciences of Philadelphia, (2) temperature and flow monitoring of the river since 1959 by the United States Geological Survey (USGS), (3) remote sensing of the Plant using aerial imagery, and (4) various ecological studies by the State of South Carolina and by industry. In addition, visiting scientists from other universities and laboratories in the United States have performed research. This appendix includes these studies as appropriate.

This appendix emphasizes Beaver Dam Creek, Four Mile Creek, Pen Branch, the Savannah River swamp, the Savannah River, and their important biota. These areas could be affected by the cooling water alternatives considered in this environmental impact statement. Important biota are those species that are (1) commercially or recreationally valuable, (2) endangered or threatened, (3) important to the well-being of the species included in categories 1 and 2, or (4) critical to the structure and function of the ecosystem.

C.2 SOILS

Soils are an important component of the environment because they influence the occurrence and distribution of the vegetation, wildlife, and potential land use. Figures C-1, C-2, and C-3 show the distribution of soils in the vicinity of C-Reactor, K-Reactor, and the D-Area coal-fired powerhouse, respectively; Table C-1 lists the characteristics of the soils shown in these figures. The C-Reactor soil map covers an area of approximately 1670 acres, while the K-Reactor map covers approximately 1770 acres. C- and K-Areas contain 19 soil types, of which udorthents and arents and urban are the most prevalent. These soils consist of material that has been previously deposited or material that remains after some of the soil has been removed; the material contains fragments or discontinuous layers of diagnostic horizons or layers. Streambed soils of Four Mile Creek and Indian Grave Branch consist primarily of Osier loamy sand; reactor operations have scoured and eroded these soils. The

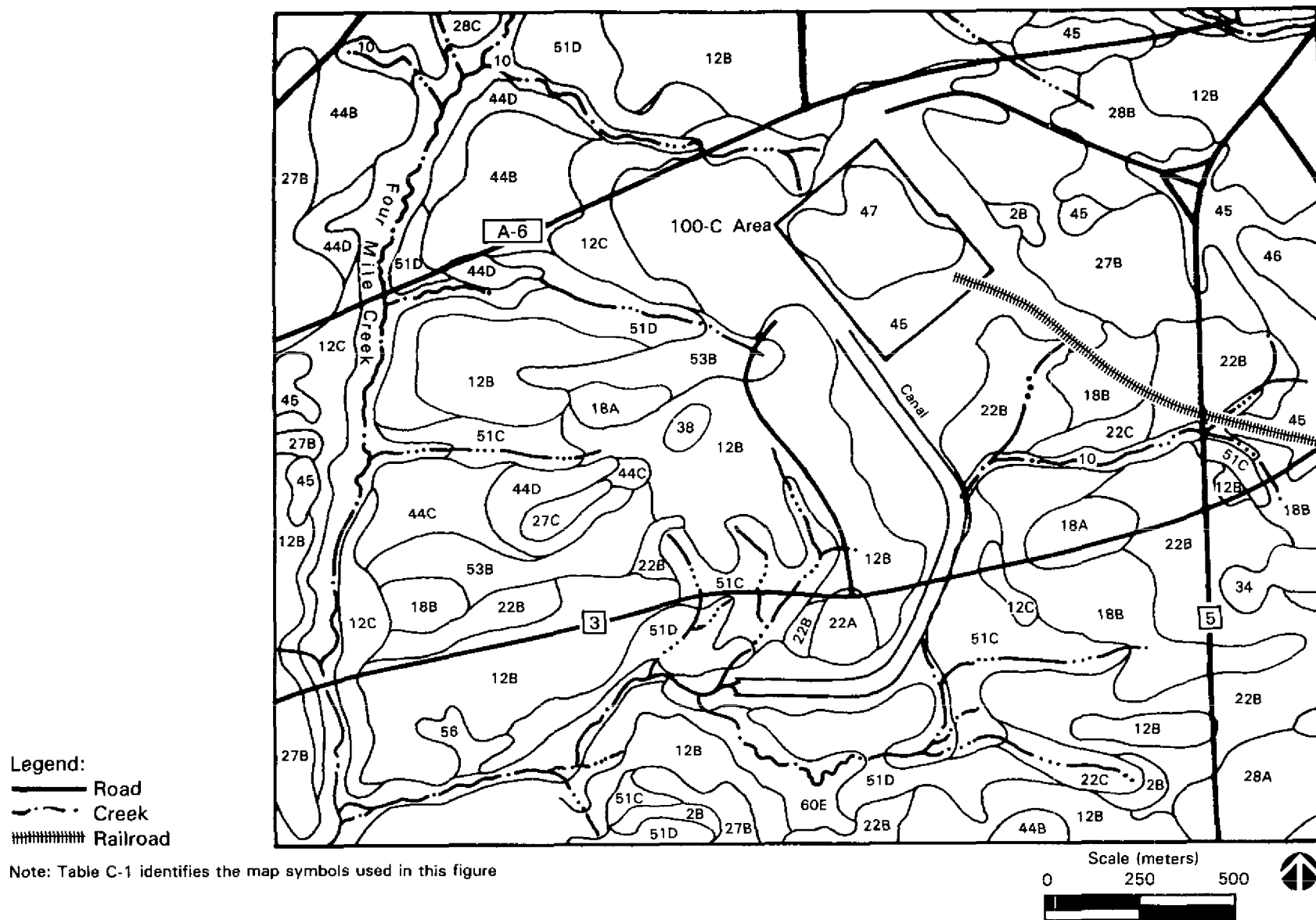
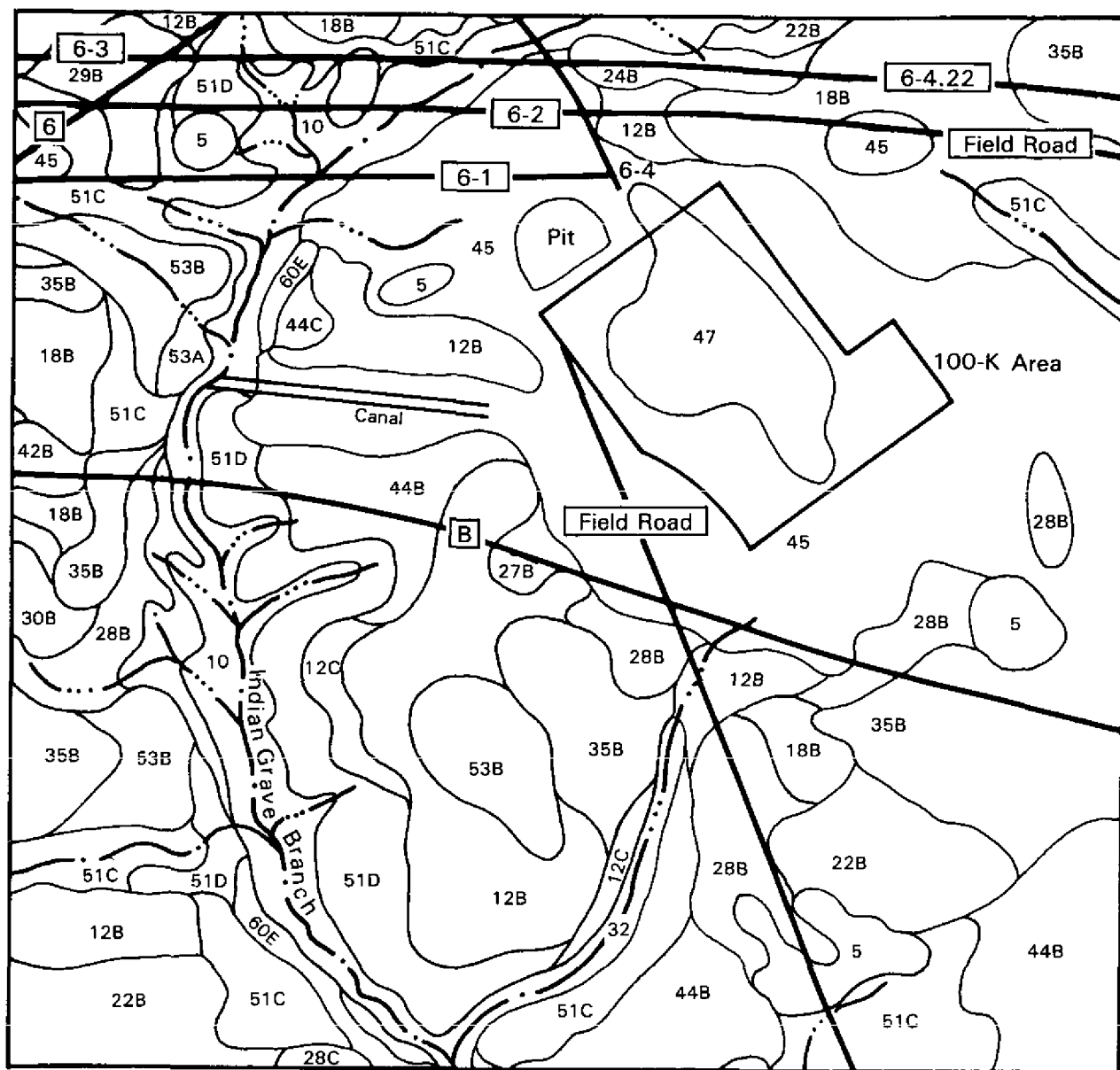


Figure C-1. Distribution of Soil Types in the C-Reactor Area



Legend:

- Road
- - - Creek

Note: Table C-1 identifies the map symbols used in this figure

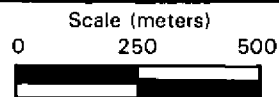


Figure C-2. Distribution of Soil Types in the K-Reactor Area

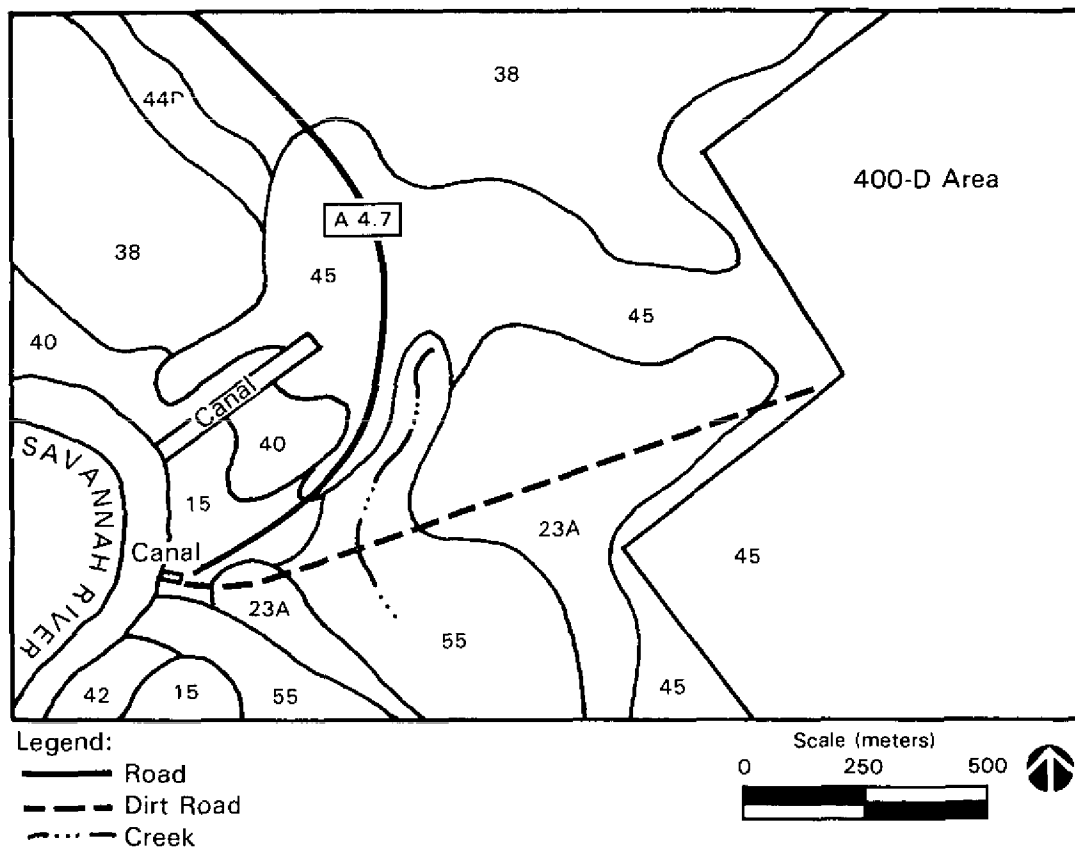


Figure C-3. Distribution of Soil Types in the D-Area

Table C-1. Occurrence, Distribution, and Selected Characteristics of Soils Surrounding C-Reactor, K-Reactor, and D-Area^a

Map symbol	Soil name	Texture (A horizon)	Drainage class
2	Ailey	Loamy sand	Well drained
5	Arents and udorthents	Sand or loam or sandy clay loam	Poorly drained
10	Osier	Loamy sand	Poorly drained
12	Blanton	Sand	Well drained
15	Tawcaw	Silty clay	Poorly drained
18	Dothan	Loamy sand	Well drained
22	Fuquay	Loamy sand	Well drained
23	Smithboro	Silt loam	Poorly drained
27	Lakeland	Sand	Well drained
29	Neeses	Loamy sand	Well drained
30	Norfolk	Loamy sand	Well drained
34	Ogeechee	Loamy fine sand	Poorly drained
35	Orangeburg	Loamy sand	Well drained
38	Rembert	Sandy loam	Poorly drained
40	Shellbluff	Loam	Poorly drained
42	Toccoa	Clay loam	Well drained
44	Troup	Sand	Well drained
45	Udorthents and arents	Loam	Poorly drained
46	Udorthents-Urban	Sandy clay loam	Well drained
47	Urban	Variable	Variable
50	Vaucluse	Loamy sand	Well drained
51	Vaucluse-Ailey complex	Loamy sand	Well drained
53	Wagram	Loamy sand	Well drained
55	Chastain	Loam	Poorly drained
56	Williman	Loamy fine sand	Poorly drained

a. Additional information for Figures C-1, C-2, and C-3: Capital letters that follow numerical map symbols designate slope classes: A = 0-2 percent, B = 2-6 percent, C = 6-12 percent, D = 12-18 percent, E = 18-25 percent.

dominant texture of the surficial horizons is loamy sand and sand; slopes typically range less than 12 percent, and most soils are well drained.

Figure C-3 shows the distribution of soils between the D-Area powerhouse and the Savannah River. The D-Area soil map covers an area of approximately 880 acres and consists of five major soil types. The udorthents-arents soil complex comprises more than 50 percent of the area. These soils consist of deposited material or material that remains after the surface layers have been removed or disturbed. The remaining soil types consist of Chastain clay loam, Smithboro loam, Tawcaw silty clay, Shellbluff loam, and Toccoa clay loam, all of which are frequently flooded and, except for the Toccoa series, are poorly drained. The Toccoa series is moderately well drained with good permeability.

C.3 VEGETATION - GENERAL SITEWIDE

The Savannah River Plant is located in an area where the oak-hickory-pine forest and the southern mixed forest intermingle (Kuchler, 1964). The southern floodplain forest (Kuchler, 1964), which adjoins major rivers such as the Savannah, is present. Dominant canopy species of the oak-hickory-pine forest include hickory, shortleaf and loblolly pine, white oak, and post oak. Beech, sweetgum, magnolia, slash and loblolly pine, white oak, and laurel oak characterize the canopy of the southern mixed forest. Typically, the southern floodplain forest consists of tupelo, many species of oak, and bald cypress. Species representative of each forest type exist on the Savannah River Plant. In addition, farming, fire, adaptive features, and topography have strongly influenced SRP vegetation. No virgin forest is in the region (Braun, 1950).

Since 1952, the U.S. Forest Service has managed the land surface at the Savannah River Plant for the Department of Energy and its predecessors. The Forest Service manages the land for multiple-use purposes, including environmental and ecological research areas, wildlife management areas for threatened or endangered species, and timber management areas (USDA, 1983).

Table C-2 summarizes the nine major land cover classes for SRP. The dominant land-use type is upland pine/hardwood (70.1 percent) followed by wetland (20.4 percent). The SRP wetlands are about 66 percent bottomland hardwood forests, primarily along streams and in the river swamp. A relatively small percentage (14 percent) of SRP wetlands are cypress and tupelo swamp forest, found predominantly in the Savannah River swamp. Normally, scrub-shrub and emergent marsh areas occur in thermal and post-thermal areas (Du Pont, 1985).

Table C-3 summarizes the wetland land-use types for the major SRP stream wetland communities.

C.3.1 FOUR MILE CREEK

Four Mile Creek, with Beaver Dam Creek, drains more than 22,480 acres. The Four Mile Creek floodplain has approximately 1900 acres of wetlands, primarily bottomland hardwood (72 percent) (Table C-3). Downstream from C-Reactor, open water and emergent marsh near the stream have replaced the original hardwood community. Away from the thermally affected areas in the floodplain, there is a hardwood canopy occupying 445 acres. Overall, C-Reactor discharges have affected about 1147 acres of Four Mile Creek wetlands. Discharges from F- and H-Areas and beaver activity have flooded original bottomland hardwood areas above the K-Reactor outfall, allowing scrub-shrub (260 acres) and emergent marsh (50 acres) wetlands to become established (Du Pont, 1985).

C.3.2 PEN BRANCH

Pen Branch and Indian Grave Branch drain about 13,590 acres above the swamp. Indian Grave Branch receives the effluent cooling water from K-Reactor. Pen Branch has about the same amount of wetlands (1725 acres) as Four Mile Creek (Table C-3). Similar to Four Mile Creek, emergent marsh (115 acres) and water (145 acres) are common below the K-Reactor discharge. Some hardwoods exist on the outer perimeter of the thermally affected areas (325 acres), but most

Table C-2. Land Use Types^a

Land cover class	Area (acres)	Percentage
Upland pine/hardwood	135,100	70.1
Clear areas/power lines	11,200	5.8
Roads	4,100	2.1
Production areas	3,100	1.6
Subtotal	153,500	79.6
Wetland		
Bottomland hardwoods	25,900	13.4
Cypress-tupelo	5,500	2.9
Water ^b	4,400	2.3
Scrub-shrub	1,900	1.0
Emergent marsh	1,500	0.8
Subtotal	39,200	20.4
Total	192,700	100.0

a. Adapted from Du Pont, 1985.

b. Includes Savannah River.

occur in nonthermal tributaries (340 acres) or upstream of the K-Area cooling water releases (Du Pont, 1985).

C.3.3 BEAVER DAM CREEK

Beaver Dam Creek is a small stream that conveys thermal effluents from the D-Area coal-fired powerhouse. The creek is located 1 to 3 kilometers west of Four Mile Creek. A narrow band of bottomland hardwoods and scrub-shrub forest borders the stream from the D-Area process-water outfall to the Savannah River swamp (Du Pont, 1985).

C.3.4 SAVANNAH RIVER SWAMP

About 9400 acres (8 percent) of the Savannah River swamp forest lies on the Savannah River Plant from Upper Three Runs Creek to Steel Creek. The swamp is primarily cypress-tupelo forest (47 percent) and drier bottomland-hardwood islands (40 percent; Table C-4). On the islands, a few pine trees are able to survive (2.2 percent). The remainder of the swamp consists of scrub-shrub vegetation communities near the entry points of the thermal and post-thermal streams. Dense cypress-tupelo forest has been replaced by the mixture of scrub-shrub, and persistent and nonpersistent marsh vegetation in these delta areas. Delta areas comprise about 15 percent of the swamp, have more plant heterogeneity, and are changing (Du Pont, 1985).

Table C-3. Areas of Major SRP Stream Corridor
Wetlands Communities (acres)^a

Stream system	BH	SS	EM	CT	W	Total	Percent of total
Four Mile Creek							
Above C-Reactor (nonthermal)	925	255	50	0	0	1230	
Below C-Reactor (thermal)	445	0	65	0	150	660	
Total	1,370	255	115	0	150	1,890	8.3
Pen Branch							
Above K-Reactor (nonthermal)	725	60	0	0	0	785	
Below K-Reactor (thermal,	325	0	115	0	145	585	
nonthermal tributaries)	340	5	10	0	0	355	
Total	1,390	65	125	0	145	1,725	7.6
Other (Upper Three Runs,							
Lower Three Runs,							
Steel Creeks)	18,170	645	260	15	35	19,125	84.1
Total SRP	20,930	965	500	15	330	22,740	

a. Adapted from Du Pont, 1985.

Abbreviations:

BH - Bottomland hardwoods
 SS - Scrub-shrub
 EM - Emergent marsh
 CT - Cypress-tupelo swamp forest
 W - Open water

C.4 WILDLIFE

The Savannah River Plant was approximately two-thirds forested and one-third cropland and pasture when the U.S. government acquired it 35 years ago (Dukes, 1984). The abandoned fields were allowed to pass through vegetational succession or were planted in pine. The Plant is now 90 percent forested. The Plant is large, topographically variable, and diverse in vegetational history. It is in an area where major habitat types come together and interperse. Human access is limited; therefore, faunal and floral diversity and abundance are high (DOE, 1984).

Because the proposed alternatives will primarily affect the fauna in the floodplains/wetlands, this section emphasizes species that depend on floodplain/wetland habitats for some part of their life cycle.

Table C-4. Area of Land Cover Classes Found in
SRP Swamp (March 31, 1981)^{a, b}

Class	Area (acres)	Percent of swamp
Persistent emergent marsh (PE)	135	1.4
Nonpersistent emergent marsh (NPE)	375	4.0
Scrub-shrub (SS)	385	4.1
Mixed deciduous swamp forest (MDSF)	4430	47.2
Mixed deciduous bottomland forest (MDBF)	3775	40.2
Needle-leaved evergreen forest (NEF)	205	2.2
Open water in swamp (W) ^c	65	0.7
Unclassified (U)	20	0.2
Total	9390	100.0

a. Obtained by analyzing multispectral scanner data (2440 meters AGL) provided by the Energy Measurements Group of EG&G, Las Vegas, Nevada.

b. Adapted from Du Pont, 1985.

c. Does not include 545 acres of Savannah River water adjacent to the swamp; probably includes some algal beds.

C.4.1 AMPHIBIANS AND REPTILES

Of the more than 90 species of reptiles and amphibians known to occur at the Plant, 61 use the SRP streams and wetlands. Most of these species inhabit post-thermal stream and swamp habitats in the vicinity of Steel Creek (Du Pont, 1985). The following list (adapted from Du Pont, 1985) contains the semi-aquatic species of reptiles and amphibians characteristic of SRP streams and swamps:

Amphibians

Salamanders - greater siren
two-toed amphiuma

Frogs - green treefrog
bird-voiced treefrog
bullfrog
bronze frog
pickerel frog
pig frog

Reptiles

Snakes - brown water snake
banded water snake
red-belly water snake
mud snake
rat snake
rainbow snake
cottonmouth

Turtles - snapping turtle
 stinkpot
 striped mud turtle
 slider turtle
 river cooter
 Florida cooter

Alligators - American alligator

Other species might occasionally occupy these habitats. A complete listing of species is in Du Pont, 1985.

No amphibians or reptiles persist on a routine basis in areas of severe thermal alteration. However, some species of frogs live in aquatic habitats that experience elevated temperatures and have deposited eggs in aquatic sites where lethal temperatures occurred (Du Pont, 1985).

Frogs and toads exhibit life history changes under elevated thermal conditions, particularly as tadpoles, by developing and metamorphosing more rapidly and at a smaller size than larvae living under normal temperature conditions (Du Pont, 1985).

The slider is the most prevalent species of turtle. This species apparently thrives in areas of moderately elevated water temperatures where it experiences faster growth rates and attains larger body sizes than turtles from local natural habitats. This can be attributed to improved diet quality, a longer growing season, and more rapid ingestion rates (Du Pont, 1985).

The striped mud turtle has been collected near the thermally elevated delta of Pen Branch. Original captures of this species were near Steel Creek before L-Reactor shutdown in 1968. No biological responses of this species to thermal conditions have been identified (Du Pont, 1985).

American alligators inhabit thermally affected streams such as Beaver Dam Creek and refuge areas along Four Mile Creek and Pen Branch (see Section C.6 details). A few other reptile species, primarily water snakes and turtles, might also occur in these areas, but not in numbers characteristic of ambient-temperature streams in the region (Du Pont, 1985).

C.4.2 AVIFAUNA

Several researchers have studied SRP avifauna. Norris (1963) surveyed the Plant in 1963. Fendley (1978) began a study in 1973 of the wood duck in the Steel Creek drainage system that has continued to the present. Angerman has conducted winter bird counts for several years (DOE, 1984). Dukes (1984) has summarized the avifauna studies.

Biologists have identified 213 species of birds at SRP. Angerman (1979; 1980) listed 59 species during recent Christmas bird counts. Game birds, particularly quail and dove, were abundant before the U.S. Government acquired the land. For a few years, the removal of land from agriculture did not decrease the quail population. In the early 1960s, this population reached a record high but began to decline because the conversion of agricultural fields to forests reduced the carrying capacity of the land.

Wild turkey, although present at Plant acquisition, were not very numerous. In 1972, the South Carolina Wildlife and Marine Resources Department started a program at the Plant for breeding wild turkey to stock other parts of the State. Thirty-six birds were released on the Plant between 1972 and 1974. Population growth was slow at first, but the turkey population has increased greatly in the last few years. To date, about 135 turkeys have been captured to restock other areas of the State.

Waterfowl are present primarily during winter migrations. After the construction of Par Pond, winter waterfowl species increased in number and diversity. An estimated 10,000 to 15,000 ducks and coots spend the winter at the Plant. Most of these birds are on Par Pond, other large ponds, and Carolina bays. Another 1000 to 2000 ducks spend the winter in the lower swamps and on the Savannah River. Wood ducks and hooded mergansers are the only waterfowl that commonly nest at the Plant.

In general, when clearing or cutting operations open wetland areas of the swamp or streams, a suitable habitat develops for ducks, wood storks, and other birds not normally found in mature cypress and tupelo stands. The increased flows and temperatures from reactor effluents to Four Mile Creek, Steel Creek, and Pen Branch have resulted in the development of such openings in the swamp. During the summer of 1972, bird surveys conducted on the deltas of Upper Three Runs Creek, Pen Branch, and Steel Creek in areas with similar densities of dead or living trees found no significant differences in non-aquatic bird communities in species diversity or richness in the natural (Upper Three Runs Creek), thermal (Pen Branch), and post-thermal (Steel Creek) swamps. However, more woodpeckers, crows, and herons occurred at Pen Branch than at Upper Three Runs Creek. The introduction of thermal effluents has produced a large stand of dead trees that serve as nesting and feeding sites for the large woodpecker and crow populations. Crows and herons represented more than 50 percent of the birds at Pen Branch Delta. Low numbers of these same species were seen near the open channel of Upper Three Runs Creek. When the canopy at Pen Branch was opened, suitable habitats became available to these larger species. The nonaquatic bird populations of the Four Mile Creek delta would be similar to those at Pen Branch.

A comparison of the number of mallards observed during 1982 aerial surveys in the Steel Creek delta area, Pen Branch delta, Four Mile Creek delta area, and Beaver Dam Creek revealed that this species used the delta areas of Four Mile, Steel, and Beaver Dam Creeks extensively. However, waterfowl were not observed in Pen Branch Delta. Mallard use of the Four Mile Creek delta area was generally higher than use of Steel Creek. Mallard use of the Four Mile Creek delta area was associated with open channels that branch off the main delta at a 90-degree angle. These channels are used heavily by waterfowl except when the water level is higher (flooding) or when the water is hotter.

The wood stork, an endangered species, forages on the site and is discussed in Section C.6.

C.4.3 MAMMALS

The Savannah River Plant has more than 40 species of mammals. The population of a few species increased rapidly and some species decreased after the Government closed the Plant to the public in 1952. The most notable expansion

was in the deer herd; the present population is estimated at about 3500. The population grew so rapidly that by the mid-1960s deer-vehicle collisions were common and range deterioration was apparent. Controlled public hunts were started in 1965 to reduce the deer population. From 1965 to 1983, hunters harvested an average of 1126 deer annually.

When the occupants relocated in 1952 for SRP, they abandoned some domestic hogs that multiplied and became detrimental to young forest plantations. Initially, a controlled program of shooting and trapping was used to reduce the hog population. Currently, deer hunters can shoot these feral hogs, and through 1983 had eliminated about 700. The present estimated population of feral hogs is between 500 and 1000. Except for deer, beaver, and feral hogs there is no authorized predation at SRP.

The following eight species of mammals are considered semiaquatic and are generally associated with the wetland/floodplain habitats:

Order Insectivora - Shrews and Moles

Family Talpidae

Condylura cristata - Star-nosed mole

Order Lagomorpha - Rabbits and Hares

Family Leporidae

Sylvilagus palustris - Marsh rabbit

Order Rodentia - Rodents

Family Castoridae

Castor canadensis - Beaver

Order Rodentia - Rodents (continued)

Family Cricetidae

Ondatra zibethicus - Muskrat

Oryzomys palustris - Rice rat

Order Carnivora - Carnivores

Family Procyonidae

Procyon lotor - Raccoon

Family Mustelidae

Lutra canadensis - River otter

Mustela vison - Mink

Order Marsupialia - Marsupials

Family Didelphidae

Didelphis marsupialis - Opossum

None of these semiaquatic mammals inhabit reactor effluent streams during periods of elevated water temperatures. Beaver and otter, however, reoccupy these streams within 24 hours of reactor shutdown (Du Pont, 1985).

C.5 AQUATIC BIOTA

Six major aquatic habitat types occur at SRP: small ponds, Carolina bays, reservoirs, streams, and the Savannah River and its associated floodplain swamp. The surface areas of these waters vary in size, from less than 1 acre to about 2700 acres. Flows in the various streams range from intermittent to more than 11 cubic meters per second.

Water flow patterns through the swamp system bordering the Savannah River are complex; these patterns change depending on water levels in the Savannah River. Patterns are quite diverse; distinct water courses alternate with braided channels and broad flats of barely perceptible water movement. Many fish species use the swamp system as a spawning and rearing ground. Its use depends on high water levels, which increases spawning habitat. The swamp is one of the most variable habitats, exhibiting depth fluctuations of 4 meters or more along with the input of thermal effluents.

C.5.1 AQUATIC FLORA

Attached algae (periphyton) are the predominant primary producers in running-water environments like the Savannah River. Much of the phytoplankton (floating algae) community consists of true planktonic forms, as well as detached periphytic forms, that are discharged from upstream reservoirs and from backwaters and tributary streams.

Diatoms dominate the algal flora of the Savannah River. Although blue-green algae are at times an important component, particularly at upstream locations that are subject to organic enrichment from municipal effluents, industrial effluents, and agricultural runoff. The greatest algal diversity consistently occurs during the summer, coincident with low river flow and decreased turbidity, which allows greater light penetration.

Approximately 400 species of algae have been identified from the Savannah River near SRP (Patrick, Cairns, and Roback, 1967). Since 1951, when algal studies began, the diversity has decreased. Patrick, Cairns, and Roback (1967) suggested that this reflects an increase of organic loading to the river from the area above the Plant (ANSP, 1961, 1974).

Aquatic macrophytes in the river, most of which are rooted, are limited to shallow areas of reduced current in oxbows and along the shallow margins of tributaries. Eight species of vascular plants have been identified from the river adjacent to SRP; the most abundant are water milfoil, hornwort, alligator weed, waterweed, and duck potato.

Flora are greatly reduced in the SRP streams that receive thermal effluents, reflecting the influence of high flows and elevated water temperatures. The thermal gradient ranges from temperatures too high for most living organisms (70°C), through a thermophilic bacteria and algal zone, to near-ambient temperatures where the water enters the Savannah River. In addition, the

streams are sufficiently narrow to produce nearly horizontal and vertical thermal constancy; thus, the only refuges from the hot water are in tributaries or adjacent sloughs. Reactor effluent has increased the total flow to 10-20 times the normal stream flow. This flow has broadened and eroded the streambeds; eliminated rooted, aquatic vascular plants (macrophytes); reduced the overhead canopy, exposing the stream to sunlight; and accumulated silt deposits in some peripheral zones along the banks.

C.5.1.1 Beaver Dam Creek

Beaver Dam Creek immediately below the D-Area discharge structure is characterized by a deep (1 to 2.5 meters) channel and a substrate of shifting sand, fly ash, organic deposits, and occasional clay outcrops (Du Pont, 1985). Riparian vegetation is dominated by a narrow band of bottomland hardwoods and scrub-shrub forest, where wax myrtle, tag alder, willow, and buttonbush are dominant. Emergent macrophytes are present in off-channel areas, such as in oxbows, behind sand bars, and in swamp areas along the margins of the stream near the delta. These areas are dominated by cattail, cutgrass, and water primrose. Aquatic flora is dominated by thermophilic bacteria and blue-green algae (Du Pont, 1985).

C.5.1.2 Four Mile Creek

A relatively deep (0.3 to 1.5 meter), fast-flowing (about 140 centimeters per second) zone occurs where the main flow of Four Mile Creek courses toward the Savannah River (Du Pont, 1985). The flora is sparse, reflecting the influence of high flow and elevated (greater than 40°C) water temperatures. The substrate is primarily sand, organic matter, silt, and clay. In backwaters and shallow areas, particularly on clay outcrops, thick mats of blue-green algae cover the bottom. Riparian vegetation is dominated by tag alder and wax myrtle. Farther downstream toward the swamp, the stream is braided over a marsh-like area where a few standing dead bald cypress remain. In this area, defined and deeper channels are relatively free of vegetation. There are, however, thick growths of emergent macrophytes dominated by sedges, cutgrass, false nettle, and water purslane. In the shallower areas, thick mats of bluegreen algae cover the bottom.

C.5.1.3 Pen Branch

The upper reaches of Pen Branch are characterized by a substrate of sand and silt clay, while deep organic deposits occur in the many side channels (Du Pont, 1985). Blue-green algal mats similar to those in Four Mile Creek cover the substrate. Riparian vegetation includes sedges, grasses, wax myrtle, and buttonbush. Duckweed is abundant in the many side pools and channels.

The delta region of Pen Branch is characterized by an open and closed canopy of living and dead bald cypress and tupelo. Many channels braid through the area and the flow is generally in a shallow sheet. The dominant vegetation consists of smartweed, arrowhead, creeping burhead, water primrose, sedges, and duckweed. Fewer emergent plants are located at the closed canopy areas of the delta.

C.5.2 AQUATIC FAUNA

C.5.2.1 Macroinvertebrates

The structure and function of macroinvertebrate assemblages can indicate longterm conditions in a stream, due to their sensitivity to stress from pollution, and can be used in water quality evaluation (Weber, 1973). Thermal discharges have complex effects on macroinvertebrate communities (Hutchinson, 1976; Ward and Stanford, 1982). Increased water temperatures can accelerate or delay the emergence patterns of aquatic insects (Wise, 1980) and increase or decrease the number of generations (Parkin and Stahl, 1981; Rodgers, 1980). In some cases, elevated thermal regimes can significantly reduce species richness (Ferguson and Fox, 1978; Howell and Gentry, 1974). Other macroinvertebrate taxa can respond positively to increased water temperatures. For example, relative abundances of oligochaetes, nematodes, gastropods, and chironomid midges increase with thermal enrichment (Nichols, 1981; Rasmussen, 1982; Laybourn, 1979; Wood, 1982; Vincent, 1967; Ferguson and Fox, 1978).

To evaluate the response of macroinvertebrates to thermal stress and the long-term recovery of the macroinvertebrate community, samples were collected from nonthermal (Meyers Branch), thermal (Beaver Dam Creek, Four Mile Creek, and Pen Branch), and post-thermal (Steel Creek) streams, and from swamp locations on SRP between November 1983 and May 1984 (Du Pont, 1985). In addition, samples were collected at the mouths of Upper Three Runs Creek, Steel Creek, and Lower Three Runs Creek from September 1982 through August 1983 (Specht et al., 1984).

The number of macroinvertebrate taxa collected from each stream station varied considerably between thermal and nonthermal stations (Table C-5). The thermally perturbed sites had the fewest taxa. Many of the taxa recorded at these sites were not resident species, but were species that had invaded and colonized during reactor shutdown periods; most were eliminated when the reactor restarted.

In general, fewer macroinvertebrate taxa and lower densities of organisms were collected from thermal sites than from post-thermal or nonthermal sites (Table C-5). The macroinvertebrate communities of the thermal sites were dominated by oligochaetes (segmented worms), nematodes (round worms) and Diptera (primarily midges), while thermally sensitive taxa, such as mayflies, stoneflies, and caddisflies were absent or occurred in very low densities. Nonthermal and post-thermal sites exhibited more diverse assemblage of macroinvertebrate taxa. At thermal sites, collector-gatherers clearly dominated the macroinvertebrate functional groups, while at nonthermal sites there was a more even distribution of functional groups, indicative of a more balanced biological community.

C.5.2.2 Fish

The Savannah River and its associated swamp and tributaries exhibit a diverse fish fauna typical of other southeastern coastal plain rivers and streams. Many ecological studies during the past 30 years have included the adult fish of the Savannah River. Matthews (1982) reviewed those studies published by the Academy of Natural Sciences of Philadelphia between 1951 and 1976.

Table C-5. Composition of Stream Macroinvertebrate Community, Presented as Sum of Densities (no./m²), December 1983 - May 1984^a

Taxa	Stations ^b							
	Mildly thermal		Severely thermal		Nonthermal			
	1	2	3	4	7	8	11	12
Coelenterata	75	0	0	0	0	0	84	0
Turbellaria	0	0	0	0	10	17	117	8
Nematoda	12,747	4,965	6,707	2,763	3,750	1,205	10,284	5,221
Annelida								
Oligochaeta	19,718	412	6,178	45,612	15,185	18,001	8,812	7,923
Hirudinea	0	0	0	0	0	0	75	0
Crustacea								
Isopoda	0	0	0	0	8	0	83	0
Amphipoda	302	2	8	84	385	27	302	1,001
Decapoda	0	0	0	0	0	0	0	0
Hydracarina	557	8	6	75	640	210	2,354	590
Insecta								
Collembola	0	8	0	0	8	8	8	8
Odonata	153	0	0	0	0	302	0	75
Ephemeroptera	17	86	87	161	3,727	4,511	4,987	1,871
Plecoptera	0	0	0	0	385	2,172	2,455	2,955
Hemiptera	0	0	0	0	0	0	0	0
Megaloptera	0	0	0	0	49	6	2	17
Neuroptera	0	0	0	0	0	0	0	0
Trichoptera	127	151	11	120	5,347	2,489	2,981	4,368
Lepidoptera	0	0	0	0	0	0	8	0
Coleoptera	17	0	42	97	2,022	1,415	1,786	1,058
Diptera	5,860	3,023	19,575	13,287	100,199	66,233	76,290	84,085
Gastropoda	1,971	17	358	1,512	75	379	22	316
Pelecypoda	4,828	0	2	0	302	3,779	75	12,828

a. Source: Du Pont, 1985.

b. Stations 1 (Beaver Dam Creek), 2 and 3 (Four Mile Creek), 4 (Pen Branch), 7 and 8 (Steel Creek), 11 and 12 (Meyers Branch).

Bennett and McFarlane (1983) summarized the general distribution of fish within the major drainage systems of the Savannah River Plant. McFarlane, Frietsche, and Miracle (1978) and Dudley, Mullis, and Terrell (1977) reported the results of fisheries studies in the portion of the river near the Plant. In addition, the Georgia Game and Fish Division (1982) reported on an electro-fishing survey conducted at 24 locations between the New Savannah River Bluff Lock and Dam and Port Wentworth. Rulifson, Huish, and Thoesen (1982) compiled data on anadromous species, many of which are important in the Savannah River. The most intensive study to date of the fish community of the SRP streams and the Savannah River (Du Pont, 1985) began in 1983.

This section summarizes the influence of thermal effluents on the fish community, specifically the distribution and abundance of adult and larval fish communities in nonthermal, post-thermal, and thermal streams; the effects of entrainment and impingement of adults and ichthyoplankton; the movement of fish into thermal streams; and the thermal tolerance of larval fish (Du Pont, 1985).

Fishes of Savannah River Plant Streams

Adult Fish of SRP Streams

Adult fish sampling began in September 1983 in nonthermal (Meyers Branch), thermal (Pen Branch and Four Mile Creek), and post-thermal (Steel Creek) streams (Figure C-4).

Nonthermal Streams - Relative abundance was greatest at the Meyers Branch station near Road 9 during the March 17 collection (Table C-6). The collection (401 fish) was dominated numerically by the yellowfin shiner (63 percent), bluehead chub (7 percent), pirate perch (5 percent), tessellated darter (5 percent), redbreast sunfish (4 percent), and spotted sunfish (3 percent). Steel Creek near Road B exhibited similar species composition and abundance during the March 10 collection; this collection (270 fish) was composed of 14 species and was dominated by yellowfin shiner (52 percent), bluehead chub (10 percent), northern hogsucker (9 percent), redbreast sunfish (9 percent), and flat bullhead (5 percent).

Post-Thermal Streams - The March 14, 1983, collection (Table C-6) from Steel Creek represented 23 species and 292 individuals. This sample exhibited the greatest species diversity, possibly due to its proximity to the Savannah River swamp. The collection was dominated by shiners (75 percent), darters (6 percent), and bullheads and madtoms (12 percent). This assemblage is a mixture of species usually associated with both stream channels and pools, backwaters, and vegetated areas along the channel.

Thermal Streams - Three locations were sampled on Pen Branch upstream of the K-Reactor outfall. A sample of site PBI, collected on April 2, 1984, was dominated by species associated with benthic-detritus microhabitats; it consisted of 76 individuals and 10 species (Table C-6). This sample was dominated by the mud sunfish (30 percent), brown bullhead (17 percent), dollar sunfish (16 percent), lake chubsucker (14 percent), and pirate perch (10 percent). Noticeably absent were species generally associated with fast-flowing water (i.e., darters).

Seventeen species of fish totaling 99 individuals were collected on March 29, 1984. Species composition was dominated by yellowfin shiner (42 percent) and sunfish (15 percent). Although there was a reduction in the total number of fish collected between September and March, the species composition remained nearly the same, indicating some degree of stability for the fauna.

One other location on Pen Branch exhibited relative abundance and species composition similar to those of the other streams surveyed. On March 26, 1984, 145 individuals representing 16 species were collected (Table C-6). The most abundant species were the yellowfin shiner (40 percent), sunfish (16.5 percent), and madtom (13.8 percent).

TC

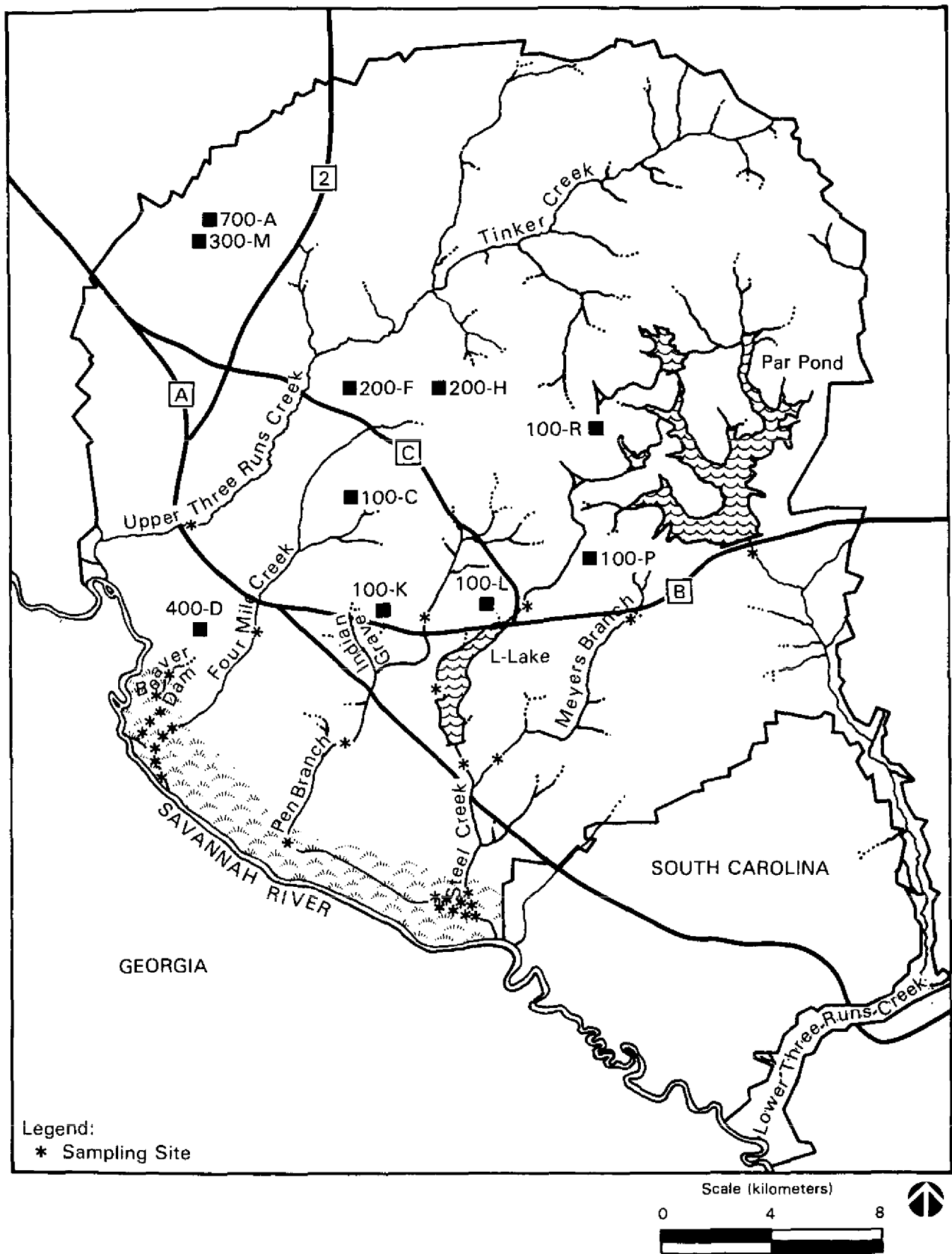


Figure C-4. Fisheries Sampling Sites in SRP Creeks

Table C-6. Number of Fish Collected in SRP Streams, September 1983 - April 1984^a

Species	Location ^b									
	Nonthermal		Post-thermal		Thermal					
	MB Sept.	MB Mar. 17	SC 1 Sept.	SC 1 Mar. 10	SC 2 Mar. 14	PB 1 Apr. 2	PB 2 Sept.	PB 2 Mar. 29	PB 3 Sept.	PB 3 Mar. 26
American eel	3 (1.0) ^c	6 (1.5)		7 (2.6)	9 (3.1)	1 (13.1)	2 (1.0)	2 (2.0)	2 (0.8)	
Pirate perch	15 (5.2)	20 (4.9)				8 (10.5)	23 (11.9)	8 (8.1)	9 (3.7)	11 (7.6)
Creek chubsucker						1 (1.3)	3 (1.6)	2 (2.0)	6 (2.5)	2 (1.4)
Lake chubsucker	3 (1.0)	2 (0.5)	1 (0.7)	2 (0.7)	2 (0.7)	11 (14.5)	1 (0.5)	1 (1.0)		
Northern hogsucker	3 (1.0)	5 (1.2)	9 (6.1)	25 (9.3)						
Banded pygmy sunfish					1 (0.3)					
Bluespotted sunfish		1 (0.2)								
Warmouth					1 (0.3)					
Dollar sunfish					2 (0.7)	12 (15.8)	1 (0.5)			
Mud sunfish	2 (0.7)					23 (30.3)	2 (1.0)	2 (2.0)		
Redbreast sunfish	19 (6.5)	15 (3.7)	19 (12.8)	25 (9.3)	6 (2.1)	1 (1.3)	9 (4.7)	5 (5.1)	16 (6.6)	17 (11.7)
Spotted sunfish	16 (5.5)	13 (3.3)	1 (0.7)	1 (0.4)	11 (3.8)		14 (7.3)	8 (8.1)	14 (5.8)	7 (4.8)
Flier					1 (0.3)					
Largemouth bass	2 (0.7)				1 (0.3)				1 (0.4)	
Unknown shiner	1 (0.3)						16 (8.3)		11 (4.6)	
Creek chub				1 (0.4)						
Bluehead chub	24 (8.2)	29 (7.2)	24 (16.2)	27 (10.0)	1 (0.3)		11 (5.7)	7 (7.1)	18 (7.5)	3 (2.1)
Pugnose shiner					1 (0.3)					
Coastal shiner					36 (12.3)					
Dusky shiner					154 (52.7)			3 (3.0)		
Yellowfin shiner	167 (57.4)	251 (62.6)	79 (53.4)	141 (52.2)	27 (9.2)		84 (43.5)	42 (42.4)	138 (57.3)	58 (40.0)
Lined topminnow					1 (0.3)					1 (0.7)
Mosquitofish				2 (0.7)	1 (0.3)					

Table C-6. Number of Fish Collected in SRP Streams, September 1983 - April 1984^a (continued)

Species	Location ^b									
	Nonthermal				Post-thermal		Thermal			
	MB Sept.	MB Mar. 17	SC 1 Sept.	SC 1 Mar. 10	SC 2 Mar. 14	PB 1 Apr. 2	PB 2 Sept.	PB 2 Mar. 29	PB 3 Sept.	PB 3 Mar. 26
Redfin pickerel	6 (2.1)	3 (0.7)				2 (2.6)	15 (7.8)	3 (3.0)		1 (0.7)
Chain pickerel					3 (1.0)			2 (2.0)	1 (0.4)	4 (2.8)
Yellow bullhead	1 (0.3)		2 (1.4)		1 (0.3)	4 (5.3)	6 (3.1)	3 (3.0)		
Brown bullhead					2 (0.7)	13 (17.1)		1 (1.0)		
Flat bullhead	2 (0.7)	6 (1.5)	8 (5.4)	15 (5.6)			4 (2.1)	1 (1.0)	4 (1.7)	6 (4.1)
Speckled madtom	6 (2.1)	9 (2.2)	2 (1.4)	17 (6.3)	15 (5.1)				9 (3.7)	7 (4.8)
Margined madtom	5 (1.7)	12 (2.9)		2 (0.1)			2 (1.0)	5 (5.1)	9 (3.7)	11 (7.6)
Tadpole madtom								1 (1.0)		2 (1.4)
Tessellated darter	12 (4.1)	19 (4.7)		1 (0.4)	12 (4.1)			4 (4.0)		1 (0.7)
Savannah darter		6 (1.5)							1 (0.4)	7 (4.8)
Sawcheek darter					1 (0.3)					
Blackbanded darter	4 (1.4)	4 (0.9)	3 (2.0)	4 (1.5)	3 (1.0)				2 (0.8)	7 (4.8)
Number of fish	291	401	148	270	292	76	193	99	241	145
Number of species	18	16	10	14	23	10	15	17	15	16

a. Source: Du Pont, 1985.

b. Location Codes: MB = Meyers Branch
 SC 1 = Steel Creek at Road B
 SC 2 = Steel Creek at Cypress Bridge
 PB 1 = Pen Branch above Road C
 PB 2 = Pen Branch at Road C
 PB 3 = Pen Branch at Road B

c. Percent composition in parentheses.

Movement of fish into the channels of thermal creeks (Pen Branch and Four Mile Creek) during reactor outages is directly related to the duration of a reactor outage. Thirty species of fish were collected in thermal creeks; 24 species were common to both Pen Branch and Four Mile Creek. Centrarchids were the fish collected most commonly, accounting for 47 percent and 45 percent of the fish collected from Pen Branch and Four Mile Creek, respectively. Other dominant taxa included the lake chubsucker (16-26 percent), the golden shiner (11-12 percent), and the longnose gar (1-14 percent).

However, samples collected from Four Mile Creek above the delta during a 50-day reactor shutdown in February 1984 were dominated exclusively by mosquitofish (Du Pont, 1985).

In general, fewer adult fish and a reduced species composition were noted from thermal streams than from post-thermal or nonthermal streams (Table C-6). The adult fish communities of the thermal streams above the outfalls were dominated by small fish (i.e., shiners and sunfish). However, during reactor shutdowns, the thermal streams below the outfall were dominated by mosquitofish. Post-thermal areas exhibited the greatest species diversity and reflected species composition typical of small headwater streams.

Ichthyoplankton of SRP Streams

Ichthyoplankton were sampled at 5 nonthermal, 16 post-thermal, and 14 thermal sites in SRP streams from mid-March through July 1984 (Paller et al., 1984). Nonthermal sites included three locations on Upper Three Runs Creek and two locations on Meyers Branch. Post-thermal sampling sites included three locations in Lower Three Runs Creek and 13 stations in Steel Creek. Three thermal streams, Beaver Dam Creek, Four Mile Creek, and Pen Branch, were sampled.

Nonthermal Streams - Ichthyoplankton abundance in the nonthermal stream-swamp area during 1984 was dominated by centrarchids (sunfish), catostomids (suckers), and percids (darters) (Table C-7). The spotted sucker was the most abundant species (55 percent) in the upper reaches of Upper Three Runs Creek, while crappie (21 percent) were the most prevalent species at the creek mouth. Ichthyoplankton densities were moderate to low (mean = 42 per 1000 cubic meters) at all stations. Meyers Branch was dominated by sunfish or bass (45 percent) and darters (30 percent). Densities were relatively low at the station near the mouth (18-67 per 1000 cubic meters), suggesting very little ichthyoplankton transport into Steel Creek from the upper reaches of Meyers Branch, which exhibited densities of 23 to 183 per 1000 cubic meters. The greater densities in the upper part of Meyers Branch might be related to more suitable spawning habitat. Several beaver dams in this area might provide good habitat for centrarchid spawning.

Post-Thermal Streams - During 1984, a total of 2785 ichthyoplankters were collected from Steel Creek and Lower Three Runs Creek (Table C-7). Relative abundance was much higher than that found in the nonthermal or thermal streams and was primarily the result of the locations of the sample collections. Generally, densities at swamp and creek mouth stations were substantially higher than at creek stations upstream from the swamp. The most dominant taxa during all collections were centrarchids (sunfish and bass, 28 percent),

Table C-7. Number and Relative Abundance of Ichthyoplankton Collected from Nonthermal, Post-Thermal and Thermal Creeks of the Savannah River Plant March 14 - June 3, 1984

Taxa	Onsite creeks ^b							
	Nonthermal		Post-thermal			Thermal		
	UTR	MB	SC	SCMB	LTR	BDC	FMC	PB
American shad			13(0.9)			1(0.5)		
Gizzard or threadfin shad	12(5.6) ^c	3(2.0)	12(0.9)		23(1.7)	19(8.6)	16(7.9)	
Blueback herring	4(1.9)		65(4.7)		20(1.5)	9(4.1)	21(10.3)	
Unidentified shad or herring	3(1.4)		14(1.0)		16(1.2)	3(1.4)	4(2.0)	
Spotted sucker	118(55.1)		14(1.0)		3(0.2)	4(1.8)		
Unidentified suckers	3(1.4)	4(2.7)	57(4.1)		15(1.1)			4(10.5)
Pirate perch			41(3.0)			3(1.4)		
Sunfish and/or bass	3(1.4)	66(44.9)	387(28.1)		626(46.1)	84(37.9)	65(32.0)	1(2.6)
Crappie	44(20.6)		34(2.5)		266(19.6)	25(11.3)	5(2.5)	
Yellow perch	2(0.9)		12(0.9)	2(4.1)	29(2.1)	1(0.5)	1(0.5)	5(13.2)
Darters	9(4.2)	44(29.9)	167(12.1)	13(26.5)	158(11.6)	20(9.0)	1(0.5)	10(26.3)
Mudminnows			5(0.4)					
Swampfish			10(0.7)					1(2.6)
Minnows	9(4.2)	14(9.5)	356(25.8)	33(67.3)	16(1.2)	15(6.8)	14(6.9)	10(26.3)
Carp	2(0.9)					1(0.5)	3(1.5)	
Pickereel			1(0.1)					
Topminnow								1(2.6)
Mosquitofish					1(0.1)			3(7.9)
Silverside		1(0.7)	29(2.1)		23(1.7)	8(3.6)	28(13.8)	
Unidentifiable ichthyoplankton	5(2.3)	15(10.2)	162(11.7)	1(2.0)	161(11.9)	29(12.6)	45(22.2)	3(7.9)
Total	214	147	1379	49	1357	222	203	38
Grand total		361		2785			463	
Number of locations sampled	3	2	13	3	3	5	6	3

a. Adapted from Du Pont, 1985.

b. Key: UTR=Upper Three Runs Creek; MB=Meyers Branch; SC=Steel Creek; SCMB=Steel Creek above Meyers Branch; LTR=Lower Three Runs Creek; BDC=Beaver Dam Creek; FMC=Four Mile Creek; PB=Pen Branch.

c. Percent composition in parenthesis.

minnows (25 percent), and darters (12 percent). Blueback herring (4 percent) were abundant in the creek mouths during April. The mean ichthyoplankton density was 175 per 1000 cubic meters during the March-to-June sampling period.

The predominant taxa collected from Lower Three Runs Creek were sunfish or bass (46 percent), crappie (20 percent), and darters (12 percent). The high densities collected in Lower Three Runs Creek were a result of samples collected immediately downstream of the Par Pond Dam (mean density = 1062 per 1000 cubic meters); they represent intense spawning activity in this tailwater area in combination with larval production in Par Pond that might have overflowed into the tailwater.

Thermal Streams - The D-Area effluent entering Beaver Dam Creek is considerably cooler than the reactor effluent (70°C) entering the other thermal creeks. Temperature data collected as part of the ichthyoplankton sampling program during 1984 indicated that the upper reaches of Beaver Dam Creek (Road A-12) averaged 20° to 25°C, while Four Mile Creek near Road A-13 averaged 30° to 45°C during the April-through-May sampling period. Temperatures decreased in Beaver Dam Creek from Road A-12 to the lowermost swamp station due to the gradual cooling of the water as it progressed downstream. However, temperatures increased at the mouth, probably due to an influx of heated water from Four Mile Creek through a channel connecting the lower reaches of Four Mile and Beaver Dam Creeks.

Ichthyoplankton densities in thermal streams ranged from total absence to very low abundance. Ichthyoplankton collected in the reactor streams between the outfalls and the swamp are believed to represent individuals that were transported into the streams from adjacent refugia, including nonthermal tributary streams, during periods of high river flow. These refugia appear to support self-sustaining (i.e., reproducing) populations of fish. In addition, ichthyoplankton abundance in thermal portions of the Savannah River swamp appears to be quite variable and strongly influenced by water levels in the Savannah River. It is also possible that the thermally impacted areas are utilized for spawning during high river flows, when flow patterns for the heated water are altered drastically.

A total of 463 ichthyoplankters was collected from the three thermal streams [Beaver Dam Creek (222), Four Mile Creek (203), and Pen Branch (38)] during the March-to-June 1984 sampling period (Table C-7). Sunfish or bass dominated the catch at both Beaver Dam Creek (38 percent) and Four Mile Creek (32 percent) while minnows (10 percent) and darters (10 percent) were dominant at Pen Branch. Beaver Dam Creek exhibited greater ichthyoplankton density and species diversity than the other thermal streams, but it did not produce the density of ichthyoplankton expected (considering the level of thermal loading observed was not much greater than in the more productive areas of the post-thermal Steel Creek delta).

C-Reactor did not operate during most of March 1984; therefore, mean temperatures in Four Mile Creek were only 5° to 10°C above Savannah River temperatures. Ichthyoplankton were not collected from the Road A station or the thermal delta during March, but were found in low densities in the swamp and creek mouth. Blueback herring were the most dominant in the delta while brook silversides were most dominant in the creek mouth.

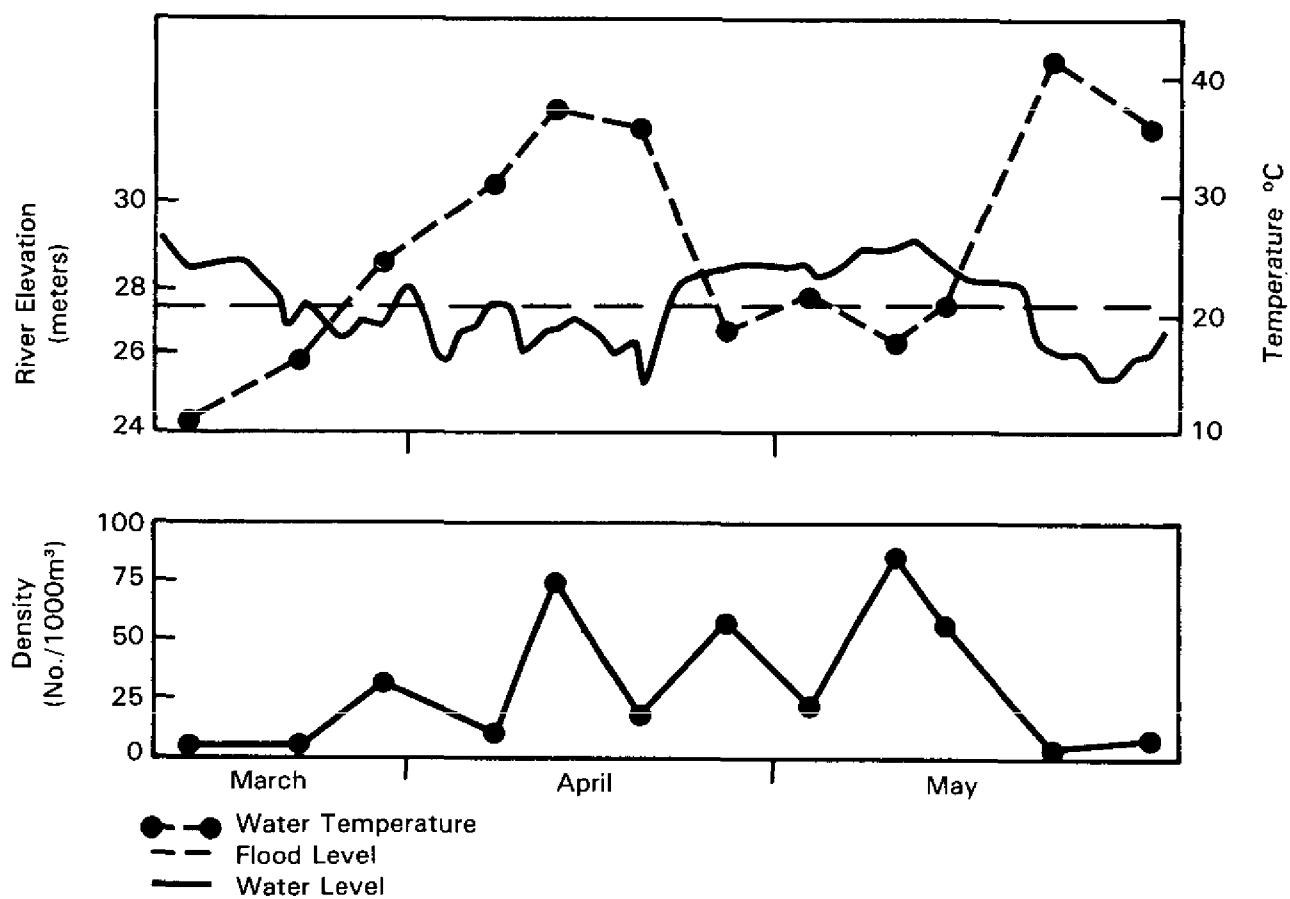
C-Reactor was operating during April and May 1984; it produced temperatures in Four Mile Creek ranging from 33.9° to 50.1°C at Road A, and from 30.1° to 44.8°C at Road A-13. As expected, Four Mile Creek produced very little ichthyoplankton in its upper reaches (the area above Road A) with the exception of brook silverside and unidentifiable eggs; these eggs probably drifted into the channel of the creek from adjacent refuge areas. Temperatures in the heated swamp were lower and much more variable (18° to 42°C) due to the alteration of water flow patterns during river flooding. The extreme temperature variability in the heated swamp was due to the intermittent intrusion of relatively cool river water into the swamp during periods of high river level (Figure C-5). The river water displaced the thermal plume and created suitable habitat for fish in areas that had been thermally unsuitable. Most of the larvae collected from the swamp during April and May apparently were spawned during periods of high river level when the swamp was inundated with river water. Some larvae were collected when the temperatures were high during April; however, these might have drifted into the thermal swamp from adjacent cool-water refuge areas.

Few ichthyoplankton (38) were collected from Pen Branch during the March-to-June 1984 sampling period. Ichthyoplankton were either absent from the samples or present in low densities. The dominant species in the delta was the mosquitofish. This species is more tolerant of high temperatures than most, with an ultimate maximum temperature of 37.3°C (Hart, 1952). Most individuals were found in somewhat cooler refuge areas along the shoreline of the main thermal channel. Darters and minnows dominated the catch from above the reactor discharge area.

Researchers observed that, generally, ichthyoplankton densities at swamp and creek mouth stations were substantially higher than at creek stations upstream from the swamp. Sampling in the vicinity of the post-thermal Steel Creek delta revealed that spawning activity differs substantially in the different microhabitats available in that area. The deep-water, open-canopy areas were clearly the most productive for ichthyoplankton, with centrarchids (sunfish and bass), cyprinids (minnows), and percids (darters) dominating the collections. Although clupeids (herring and shad) were collected in the delta/swamp areas, the numbers were much lower than the numbers observed at creek mouth stations. Generally, it appears that anadromous species make minimal use of swamp areas for spawning and restrict spawning activities to creek mouth areas.

Ichthyoplankton densities in thermal streams were low. Ichthyoplankton collected in the reactor streams between the outfalls and the swamp are believed to represent individuals that were transported into the streams from adjacent refugia, including nonthermal tributary streams. These refugia appear to support self-sustaining (i.e., reproducing) populations of fish. Ichthyoplankton that are transported into the reactor effluent streams when reactors are operating are undoubtedly killed.

Ichthyoplankton abundances in thermal portions of the Savannah River swamp are quite variable and appear to be strongly influenced by water levels in the Savannah River. During periods of high river flow, ichthyoplankton appear to be transported into the thermally impacted portions of the swamp from adjacent unimpacted areas. It is also possible that the thermally impacted areas are



Source: Adapted from Du Pont (1985)

Figure C-5. A Comparison of the Ichthyoplankton Density in the Four Mile Creek Delta with Water Temperature and Savannah River Level

utilized for spawning during high river flows, because flow patterns for the heated water are drastically altered during such periods.

Ichthyoplankton densities in Beaver Dam Creek are lower than expected considering the low degree of thermal enrichment. Factors other than temperature probably are influencing fish spawning activities in this area of the swamp.

Adult Fish of the Savannah River Swamp System

The Savannah River Swamp System (SRSS) represents a very heterogeneous system of habitats supporting a diverse fish community of 60 to 65 species. Most species are resident; however, seven are either anadromous or catadromous. Anadromous (migrating from saltwater to freshwater to spawn) species include blueback herring, American shad, hickory shad, striped mullet, mountain mullet, and Atlantic needlefish. The only catadromous (migrating from freshwater to saltwater to spawn) species is the American eel. Several recreationally and commercially important species have been collected in the swamp; thus, the SRSS could be an important spawning habitat and nursery grounds for these species. This section summarizes the data collected on the adult fish community in the swamp system from October 1983 to April 1984 (Du Pont, 1985).

Adult fish were collected at three areas in the swamp: the Steel Creek delta; the Four Mile Creek delta, and a channel near Pen Branch (near Stave Island).

More than 1500 fish representing 40 species were collected from the swamp. The high species diversity was due to the wide array of habitat types available. The Steel Creek delta sample consisted of 32 species, of which brook silversides, various shiners, and largemouth bass dominated all catches.

Species diversity at stations in the delta-swamp area of Pen Branch were similar - 21 species dominated by brook silversides and various shiners.

Four Mile Creek stations differed among themselves and also from the other three delta-swamp stations. Fifteen species of fish were collected; gizzard shad and largemouth bass were the dominant species. Compared to the other stations, minnows were poorly represented at this station.

Researchers captured 149 migratory fish. The dominant species were longnose gar (48 percent), blueback herring (23 percent), channel catfish (10 percent), and various shad (12 percent). Researchers first observed blueback herring during the first week of March, while American shad did not appear until the last week of March. Conversations with local fishermen suggest that American shad were more numerous than blueback herring or hickory shad during 1984, and that a major run of blueback herring did not occur in Steel Creek.

Several trends are evident concerning the structure of fish communities within the SRSS. It appears that the increased species composition and the dominance by centrarchids and cyprinids are attributed to the diversity of microhabitats in the area. The swamp system is composed of extensive open water channels and macrophyte beds of various size. Centrarchids (bass and sunfish) and various suckers dominated the areas with extensive cover while minnows and brook silverside were most prevalent in the shallow open-water areas beneath the closed canopy. The swamp areas below the thermal streams were lower in habitat diversity and species composition.

Fishes of the Savannah River

The following introductory information was obtained from DOE (1987) which cites the primary source documents containing the data.

TC

Streams of the southeastern Atlantic Coastal Plain generally contain a diverse fish fauna. One hundred six fish species have been reported from the Savannah River drainage basin; seventy-one species of anadromous and fresh water fish are known to occur in the river in the SRP vicinity.

TC

The Savannah River supports both recreational and commercial fisheries. Bream and largemouth bass are the species most sought after by sport fishermen in freshwater sections of the river downstream of the New Savannah Bluff Lock and Dam. Channel catfish are taken by both sport and commercial fishermen. Anadromous species of importance in the Savannah River include American shad (Alosa sapidissima), hickory shad (Alosa mediocris), Atlantic sturgeon (Acipenser oxyrhynchus), shortnose sturgeon (Acipenser brevirostrum), and striped bass (Morone saxatilis). Both shortnose sturgeon and striped bass are protected from commercial harvest, and the shortnose sturgeon is listed as an endangered species. The catadromous American eel (Anguilla rostrata) is harvested commercially in some sections of the river.

Several identifiable factors potentially affect the productivity of Savannah River fish populations. Two areas of the lower Savannah River have been identified where water quality is substantially degraded because of wastewater input: below the New Savannah Bluff Lock and Dam from Butler Creek to downstream of Spirit Creek and in the Savannah Harbor area. Potential contributors to declining anadromous fish stocks include dams and impoundments, inadequate fishway facilities, reduction in spawning habitat, reduction in nursery areas, dredge and fill projects, poor food availability, and the location, type and magnitude of effluents into the Savannah River.

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The species composition and relative abundance of Savannah River fish in the vicinity of the SRP were examined during 1982-1985 (ECS, 1983; Paller et al., 1984; Paller and Osteen, 1985; Paller and Saul, 1986). Collections were made along transects in the Savannah River and in the 1G and 3G intake canals using both electrofishing and hoop-netting techniques. Savannah River collections from four transects near the SRP intakes between RM 152.2 and 157.3 were analyzed for this evaluation. Collections were made quarterly from March 1982 to September 1985.

Scientific and common names of fish collected or known to occur in the Savannah River near SRP are presented in Table C-8. The dominant species collected in the Savannah River and the SRP intake canals during 1982-85 are presented in Table C-9. Other species comprising less than one percent of reported catches for either location or sampling gear are presented in Table C-10.

Adult Fishes of the Savannah River and Creek Mouths

This section summarizes the results of adult fish collections at 12 locations in the Savannah River, the intake canals, and the lower mouths of the five major SRP creeks. The data cover the sampling period from October 1982 to

Table C-8. Scientific and Common Names of Fish Collected or Known To Occur in the Savannah River Near the SRP

Order	Family	Species	Common Name
Acipenseriformes	Acipenseridae	<u>Acipenser oxyrhynchus</u>	Atlantic sturgeon
		<u>Acipenser brevirostrum</u>	Shortnose sturgeon
Semionotiformes	Lepisosteidae	<u>Lepisosteus osseus</u>	Longnose gar
		<u>Lepisosteus platyrhincus</u>	Florida gar
		<u>Lepisosteus oculatus</u>	Spotted gar
Amiiformes	Amiidae	<u>Amia calva</u>	Bowfin
Anguilliformes	Anguillidae	<u>Anguilla rostrata</u>	American eel
Clupeiformes	Clupeidae	<u>Alosa aestivalis</u>	Blueback herring
		<u>Alosa sapidissima</u>	American shad
		<u>Dorosoma cepedianum</u>	Gizzard shad
		<u>Alosa mediocris</u>	Hickory shad
		<u>Dorosoma petenense</u>	Threadfin shad
Salmoniformes	Umbridae	<u>Umbra pygmaea</u>	Eastern mudminnow
	Esocidae	<u>Esox niger</u>	Chain pickerel
		<u>Esox americanus</u>	Redfin pickerel Grass pickerel
Cypriniformes	Cyprinidae	<u>Cyprinus carpio</u>	Carp
		<u>Hybognathus nuchalis</u>	Silvery minnow
		<u>Hybopsis rubrifrons</u>	Rosyface chub
		<u>Nocomis leptcephalus</u>	Bluehead chub
		<u>Notemigonus crysoleucas</u>	Golden shiner
		<u>Notropis chalybaeus</u>	Ironcolor shiner
		<u>Notropis cummingsae</u>	Dusky shiner

Table C-8. Scientific and Common Names of Fish Collected or Known To Occur in the Savannah River Near the SRP (continued)

Order	Family	Species	Common Name
Cypriniformes	Cyprinidae (cont.)	<u>Notropis emiliae</u>	Pugnose minnow
		<u>Notropis hudsonius</u>	Spottail shiner
		<u>Notropis hypselopterus</u>	Sailfin shiner
		<u>Notropis leedsi</u>	Bannerfin shiner Ohoopee shiner
		<u>Notropis lutipinnis</u>	Yellowfin shiner
		<u>Notropis maculatus</u>	Taillight shiner
		<u>Notropis petersoni</u>	Coastal shiner
		<u>Notropis niveus</u>	Whitefin shiner
	Catostomidae	<u>Carpiodes cyprinus</u>	Quillback carpsucker
		<u>Erimyzon oblongus</u>	Creek chubsucker
		<u>Erimyzon sucetta</u>	Lake chubsucker
		<u>Minytrema melanops</u>	Spotted sucker
		<u>Moxostoma anisurum</u>	Silver redhorse
Cyprinodontiformes	Cyprinodontidae		Unid. killifish
Siluriformes	Ictaluridae	<u>Ictalurus brunneus</u>	Snail bullhead
		<u>Ictalurus catus</u>	White catfish
		<u>Ictalurus natalis</u>	Yellow bullhead
		<u>Ictalurus nebulosus</u>	Brown bullhead
		<u>Ictalurus platycephalus</u>	Flat bullhead
		<u>Ictalurus punctatus</u>	Channel catfish
		<u>Noturus gyrinus</u>	Tadpole madtom
		<u>Noturus insignis</u>	Margined madtom

BB-3

Table C-8. Scientific and Common Names of Fish Collected or Known To Occur in the Savannah River Near the SRP (continued)

Order	Family	Species	Common Name
Siluriformes	Ictaluridae (cont.)	<u>Noturus leptacanthus</u>	Speckled madtom
		<u>Pylodictis olivaris</u>	Flathead catfish
Percopsiformes	Amblyopsidae	<u>Chologaster cornuta</u>	Swampfish
	Aphredoderidae	<u>Aphredoderus sayanus</u>	Pirate perch
Atheriniformes	Belonidae	<u>Strongylura marina</u>	Atlantic needlefish
	Cyprinodontidae	<u>Fundulus lineolatus</u>	Lined topminnow
		<u>Fundulus chrysotus</u>	Golden topminnow
		<u>Fundulus notti</u>	Starhead topminnow
	Poeciliidae	<u>Gambusia affinis</u>	Mosquitofish
	Atherinidae	<u>Ladidesthes sicculus</u>	Brook silverside
Perciformes	Percichthyidae	<u>Morone chrysops</u>	White bass
		<u>Morone saxatilis</u>	Striped bass
	Centrarchidae	<u>Acantharchus pomotis</u>	Mud sunfish
		<u>Centrarchus macropterus</u>	Flier
		<u>Elassoma zonatum</u>	Banded pygmy sunfish
		<u>Enneacanthus chaetodon</u>	Blackbanded sunfish
		<u>Enneacanthus gloriosus</u>	Bluespotted sunfish
		<u>Lepomis auritus</u>	Redbreast sunfish
		<u>Lepomis cyanellus</u>	Green sunfish
		<u>Lepomis gibbosus</u>	Pumpkinseed
		<u>Lepomis gulosus</u>	Warmouth

BB-3

Table C-8. Scientific and Common Names of Fish Collected or Known To Occur in the Savannah River Near the SRP (continued)

Order	Family	Species	Common Name
Perciformes	Centrarchidae (cont.)	<u>Lepomis macrochirus</u>	Bluegill
		<u>Lepomis marginatus</u>	Dollar sunfish
		<u>Lepomis microlophus</u>	Redear sunfish
		<u>Lepomis punctatus</u>	Spotted sunfish
		<u>Micropterus salmoides</u>	Largemouth bass
		<u>Micropterus coosae</u>	Redeye bass
		<u>Pomoxis annularis</u>	White crappie
		<u>Pomoxis nigromaculatus</u>	Black crappie
	Percidae	<u>Etheostoma fricksium</u>	Savannah darter
		<u>Etheostoma fusiforme</u>	Swamp darter
		<u>Etheostoma hopkinsi</u>	Christmas darter
		<u>Etheostoma inscriptum</u>	Turquoise darter
		<u>Etheostoma olmstedii</u>	Tessellated darter
		<u>Etheostoma serriferum</u>	Sawcheeker darter
		<u>Perca flavescens</u>	Yellow perch
		<u>Percina nigrofasciata</u>	Blackbanded darter
		<u>Percina caprodes</u>	Logperch
	Mugilidae	<u>Mugil cephalus</u>	Striped mullet
	Agonidae	<u>Agonostomos monticola</u>	Mountain mullet
	Gobiidae	<u>Awaous tajasica</u>	River goby
Pleuronectiformes	Soleidae	<u>Trinectes maculatus</u>	Hogchoker

a. Source: DOE, 1987.

BB-3

Table C-9. Percent Composition of Abundant^a Fish Species^b Collected in the Savannah River and SRP Intake Canals, 1982-85^c

Taxa	Savannah River		Intake Canals	
	Electro- Fishing Percent	Hoop Netting Percent	Electro- Fishing Percent	Hoop Netting Percent
Flier	0.30	1.21	0.09	1.55
Redbreast sunfish	26.73	7.09	10.04	12.69
Bluegill	8.44	4.32	24.07	19.95
Spotted sunfish	5.22	0.86	1.83	1.55
Warmouth	1.25	1.04	0.85	0.26
Pumpkinseed	0.17	0.35	2.30	1.04
Redear sunfish	1.63	0.95	4.13	1.81
Dollar sunfish	2.74	0.00	8.38	0.26
Bluespotted sunfish	0.98	0.00	2.34	0.00
Largemouth bass	7.69	0.00	6.04	0.00
Black crappie	2.07	4.75	0.89	27.20
Yellow perch	1.08	0.00	6.47	0.78
Bowfin	3.83	1.04	1.91	1.04
Blueback herring	1.73	0.17	0.51	0.00
American shad	1.25	0.26	0.00	0.00
Gizzard shad	2.44	0.86	2.76	2.59
Threadfin shad	1.96	0.00	0.94	0.00
Spotted sucker	11.21	0.78	5.23	3.37
Lined topminnow	0.00	0.00	1.20	0.00
Pirate perch	1.49	0.00	0.47	0.00
Chain pickerel	3.29	0.00	10.97	0.26
Grass pickerel	1.08	0.00	1.70	0.00
Longnose gar	0.81	2.51	0.26	0.52
White catfish	0.07	8.47	0.00	0.26
Flat bullhead	0.24	31.98	0.04	11.92
Brown bullhead	0.00	1.47	0.00	0.00
Channel catfish	0.41	24.29	0.09	8.55
Brook silverside	1.29	0.00	0.94	0.00
Striped mullet	1.42	0.00	2.00	0.00
American eel	3.32	3.11	0.13	2.33
Other species	5.86	4.49	3.42	2.07

a. Species comprising greater than one percent of collections for either sampling method or location.

b. Scientific and common names of Savannah River fish species are presented in Table C-8.

c. Source: DOE, 1987.

BB-3

Table C-10. Fish Species^a Collected in Low Abundance^b in
the Savannah River or SRP Intake Canals, 1982-85^c

Mud sunfish	Eastern silvery minnow
Redeye bass	Ochoopee shiner
White crappie	Notropis spp.
Striped bass	Unidentified minnow
White bass	Golden shiner
Hybrid bass	Hogchoker
Tesselated darter	Redfin pickerel
Logperch	Esox spp.
Blackbanded darter	Spotted gar
Lake chubsucker	Florida gar
Chubsucker	Snail bullhead
Highfin carpsucker	Speckled madtom
Silver redhorse	Eastern mudminnow
Quillback carpsucker	Mosquitofish

- Scientific and common names of Savannah River fish species are presented in Table C-8.
- Less than one percent of collections for any sampling method or location identified in Table C-9.
- Source: DOE, 1987.

BB-3

August 1983, and are based on studies conducted by Environmental and Chemical Sciences, Inc., under contract to E. I. du Pont de Nemours and Company (Paller et al., 1984).

Researchers collected nearly 10,000 adult fish representing 66 species in the river, the intake canals, and the lower reaches of the major SRP creeks during the sampling period.

The electrofishing collections (Table C-11) indicated that sunfishes, especially redbreast, were the most abundant small species (except minnows), while bowfin and spotted sucker were among the most abundant large species during most or all of the year. Flat bullhead and channel catfish were important species, as indicated by hoop net collections, comprising 32 to 63 percent of the catch. Largemouth bass never comprised less than 7.9 percent of the electrofishing samples during any collection period. Other important species were American eel, white catfish, longnose gar, striped mullet, silver redhorse, chain pickerel, and quillback carpsucker.

Species composition varied due to seasonal changes in fish movement and activity (e.g., spawning). The most conspicuous change was a decrease in the relative abundance of sunfish during January (Table C-11). Bowfin, spotted sucker, flat bullhead, and channel catfish were more abundant during January. The greatest number of species was captured during May (37), possibly because of migratory movements or seasonal changes in activity related to spawning. Recruitment of young of the year might have increased the relative abundance of some species during August.

Table C-11. Percent Composition by Number and Weight of Fishes Collected Quantitatively by Electrofishing in the Savannah River and Creek Mouths, October 1982 - August 1983^a

Taxa	1982		1983					
	October		January		May		August	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Bowfin	13.6	53.3	15.1	37.9	2.4	20.6	4.8	36.4
American eel	3.6	1.3	0.3	0.3	1.2	1.4	2.4	1.7
Blueback herring	2.4	0.1	0.0	0.0	0.3	0.2	0.0	0.0
American shad	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.1
Gizzard shad	1.9	1.6	4.5	1.6	2.1	1.7	1.5	1.7
Threadfin shad	0.0	0.0	2.3	0.1	3.3	0.5	0.8	0.0
Quillback carpsucker	0.0	0.0	0.0	0.0	0.3	9.2	0.3	7.0
Spotted sucker	13.5	26.5	22.7	32.0	6.9	26.0	5.3	18.7
Silver redhorse	0.9	2.2	1.4	2.3	2.1	9.6	1.0	4.2
Unidentified redhorse	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
Golden shiner	0.0	0.0	0.3	0.1	0.5	0.1	0.4	0.0
Flier	0.0	0.0	0.9	0.1	0.3	0.1	0.0	0.0
Bluespotted sunfish	0.0	0.0	0.0	0.0	5.7	0.1	0.7	0.0
Redbreast sunfish	22.4	1.9	7.1	0.5	13.9	4.0	22.7	4.1
Pumpkinseed	0.0	0.0	0.3	0.1	0.6	0.1	1.8	0.2
Warmouth	1.2	0.1	0.0	0.0	1.8	0.4	1.2	0.2
Bluegill	11.2	0.5	2.6	0.2	5.5	1.0	9.0	1.2
Dollar sunfish	1.4	0.0	0.0	0.0	4.8	0.2	7.3	0.3
Redear sunfish	3.3	0.8	7.7	2.4	3.6	1.9	2.7	1.9
Spotted sunfish	7.1	0.9	4.8	0.2	9.3	1.3	9.3	1.2
Largemouth bass	7.9	4.0	8.5	3.9	9.8	7.8	9.0	4.9
White crappie	0.7	0.1	0.3	0.1	0.1	0.1	0.0	0.0
Black crappie	0.7	0.1	3.7	0.7	2.0	0.6	1.1	0.5
Striped mullet	1.5	1.5	1.1	0.4	2.4	4.3	6.7	9.3
White bass	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Striped bass	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Yellow perch	2.0	0.4	2.0	0.2	2.7	0.9	2.1	0.6
Pirate perch	0.9	0.1	0.0	0.0	0.9	0.1	2.1	0.0
Redfin pickerel	0.7	0.1	5.4	0.1	3.4	0.2	1.6	0.1
Chain pickerel	1.3	0.2	3.4	1.2	11.2	2.1	3.7	1.7
Mudminnow	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
Longnose gar	0.5	0.4	4.0	2.8	1.7	3.8	0.9	1.1
Florida gar	0.0	0.0	0.0	0.0	0.4	0.5	0.0	0.0
White catfish	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
Brown bullhead	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
Flat bullhead	0.0	0.0	0.3	0.1	0.2	0.1	0.1	0.2
Channel catfish	0.2	0.8	0.0	0.0	0.3	0.6	1.1	2.4
Carp	0.3	3.2	1.4	13.1	0.0	0.0	0.0	0.0
Hogchoker	0.8	0.1	0.0	0.0	0.1	0.1	0.2	0.1
Total percent	100.0	99.9	100.1	99.9	99.9	100.0	99.8	99.7
Total number	1628		352		2365		2175	
Total wt. (kg)		670.1		248.1		468.2		505.8

a. Source: Du Pont, 1985.

The sampling stations were located in four basic habitat types: the river proper, intake canals, the mouths of thermal creeks (Four Mile and Beaver Dam Creeks), and ambient creeks (Upper Three Runs, Lower Three Runs, and Steel Creeks).

In general, bluegill, black crappie, and chain pickerel were more abundant in the intake canals than in the other habitats, probably due to their preference for slow-moving water and weed beds. Redbreast sunfish were generally most abundant in the river and bowfin in the ambient creeks, especially Steel Creek. Four Mile Creek attracted numerous gar, bowfin, and gizzard shad during January, but was largely devoid of fishes during the other months. Channel catfish and various bullheads clearly dominated the hoopnet collections at all stations and seasons, probably due to gear selectivity. During the study period, the mean weekly water temperature of the thermal creeks was 14°C; it was 7°C in ambient creeks during the January sampling period. Largemouth bass and sunfishes dominated May catches at both thermal and ambient creek stations, although only 46 fish were collected in thermal creeks compared to 244 in ambient creeks. During May, the mean temperature was 31°C in the thermal creeks and 19.2°C in ambient creeks. Very few fish were collected from the thermal creeks during October or August (4 and 24, respectively). The mean temperature of the thermal creeks during the sampling periods was 27.7°C in October and 32°C in August; it was 15.0°C and 23°C, respectively, during the same months in ambient creeks.

Although the researchers did not sample small fishes and minnows quantitatively, they documented species occurrence and distribution. Species abundance was consistently less in the intake canals than in the river; mosquitofish, brook silversides, and lined topminnows were the most abundant in the canals. Small fish were absent from the mouths of Four Mile Creek and very scarce in Beaver Dam Creek during May and August. The low number of minnow species and small fish collected in these creeks paralleled the large fish collections and are probably the result of high temperatures during May and August (24.5°C to 41.2°C).

Researchers used the number of fish collected quantitatively with electrofishing to estimate the relative density (number of fish per 100 meters of shoreline) (Du Pont, 1985). The relative densities of fishes in the 1G and 3G intake canals (0.5 to 8.4 per 100 meters) were equivalent to the relative density in the river; however, the average weight of fish in the intake canals was approximately 40 percent lower than that in the river because of the predominance of bluegill and other small sunfishes. The seasonal relative abundances in the intake canals were comparable to those in the river.

Relative densities and seasonal trends in the mouths of the ambient temperature creeks were similar to those in the river, with low densities in January (0.3 to 0.5 per 100 meters) and higher densities in the other months (Table C-12). In contrast, the relative density in thermally influenced Four Mile Creek peaked during January (5.9 per 100 meters) at levels greater than those at the other transects (0.2 to 2.9 per 100 meters); this indicates a wintertime aggregation of fishes in the heated waters, which were as much as 7°C warmer than ambient river temperatures. Fish avoided Four Mile Creek during May, August, and October because of the excessively high water temperatures (29° - 41°C compared to 16° - 25°C in ambient creeks). Densities in Beaver Dam Creek during May and August (2.8 and 1.3 per 100

Table C-12. Mean Relative Density of Fishes (No./100 m of Shoreline) at Electrofishing Sample Sites in the Savannah River, Intake Canals, and Tributary Creeks, October 1982 - August 1983^a

Location	1982		1983					
	October		January		May		August	
	Total fish	Mean no./ 100 m	Total fish	Mean no./ 100 m	Total fish	Mean no./ 100 m	Total fish	Mean no./ 100 m
RIVER TRANSECTS								
RM 128.9	- ^b	-	-	-	168	7.0	83	3.5
RM 129.1	-	-	-	-	252	10.5	120	5.0
RM 137.1	123	5.1	22	0.9	70	2.9	128	5.3
RM 141.5	189	7.9	36	1.5	133	5.5	137	5.7
RM 141.7	189	7.9	70	2.9	131	5.5	145	6.0
RM 150.4	167	7.0	52	2.2	189	7.9	146	6.1
RM 150.8	133	5.5	15	0.6	155	6.5	133	5.5
RM 152.0	-	-	-	-	191	8.0	81	3.4
RM 152.2	-	-	-	-	114	4.8	87	3.6
RM 155.2	143	6.0	13	0.5	122	5.1	115	4.8
RM 157.0	123	5.1	4	0.2	70	2.9	87	3.6
RM 157.3	161	6.8	42	1.8	118	4.9	155	6.5
INTAKE CANALS								
1G RM 157.1	144	6.0	35	1.5	161	6.7	148	6.2
3G RM 155.3	121	5.0	11	0.5	201	8.4	199	8.3
CREEKS								
Lower Three Runs	-	-	-	-	73	6.1	51	5.4
Steel	69	8.6	3	0.5	97	8.1	101	8.4
Four Mile	4	0.7	47	5.9	12	1.0	8	0.7
Beaver Dam	-	-	-	-	34	2.8	16	1.2
Upper Three Runs	60	5.0	2	0.3	74	6.3	235	19.6

a. Source: Du Pont, 1985.

b. (-) locations not sampled.

meters, respectively) were higher than in Four Mile Creek, but considerably lower than those in ambient creeks or river stations. Temperatures in Beaver Dam Creek were 5° to 7°C above ambient river temperatures, but were not as high as those in Four Mile Creek.

Researchers determined the approximate distances between the capture and recapture sites for 68 fish that were tagged in the river, canals, and creeks during the sampling program (Du Pont, 1985). Ninety-one percent were recaptured within 15 days at or near the point of tagging, indicating limited short-term movements. However, tag returns by fishermen indicated that some fish undertook extensive migrations (as far as 55 miles) upstream or downstream from the tagging location over a period of weeks or months.

Ichthyoplankton Abundance in the Savannah River

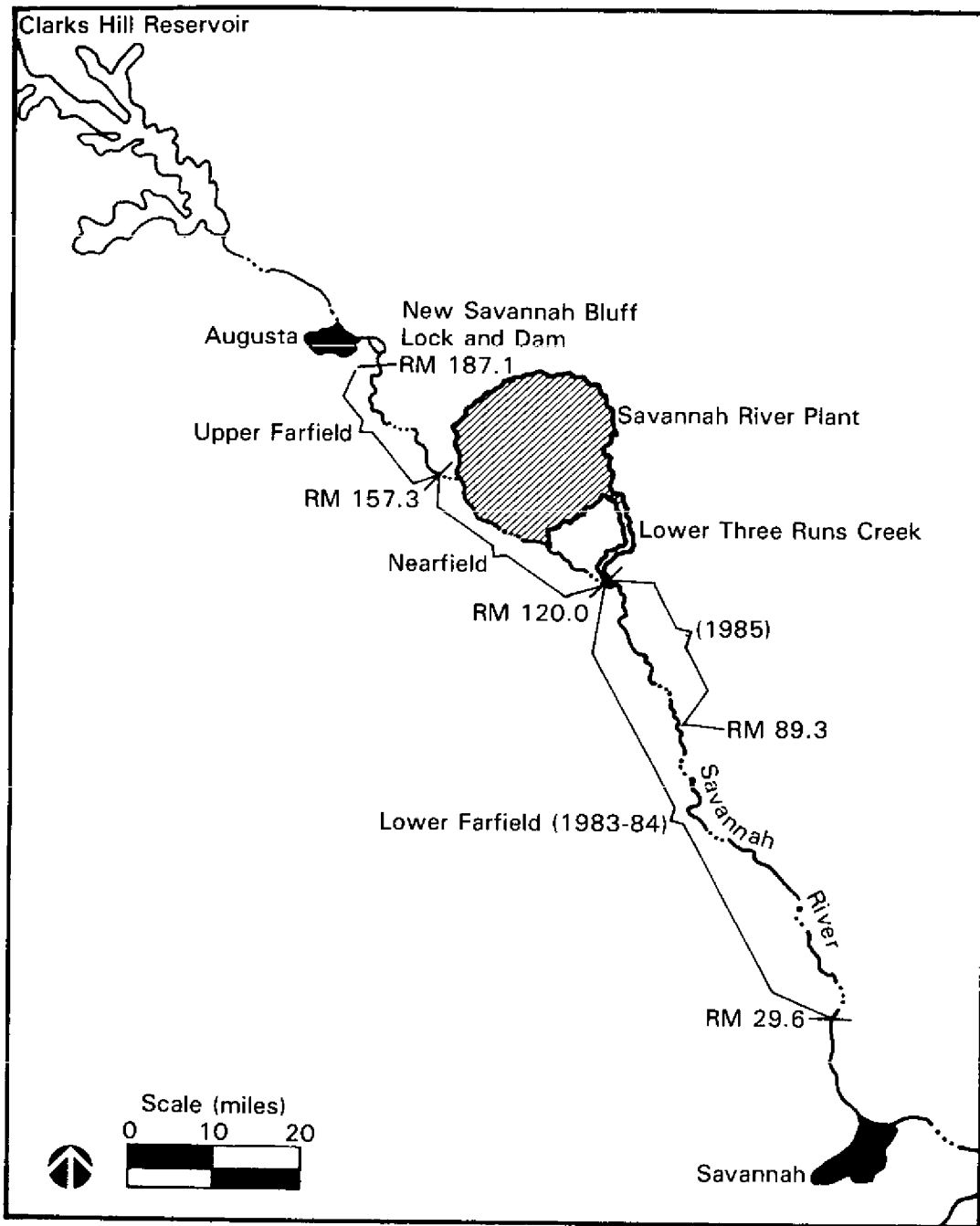
The abundance of ichthyoplankton is one measure of the reproductive success of fishes; concentrations of ichthyoplankton can indicate important spawning sites, identify impacted and control areas, and provide information for entrainment and impingement losses.

Recent studies on ichthyoplankton of the mid- and lower reaches of the Savannah River began in 1982 and ended in 1985 (ECS, 1983; Paller et al., 1984; Paller, O'Hara, and Osteen, 1985; Paller, Saul, and Osteen, 1986). The 1982 studies were restricted in scope, and included seven river transects between RM 141.5 and RM 157.3 and SRP intake canals 1G and 3G (Figure C-6, Table C-13). The 1983 and 1984 studies included 26 river transects between RM 29.3 and RM 187.1, and the two intake canals. The 1985 study was slightly truncated, and included 21 river transects between RM 89.3 and RM 187.1 and the two intake canals. Sampling in 1982 was conducted on alternate weeks from March through August, while in subsequent years, sampling was conducted weekly from February through July. This consideration of entrainment at the SRP will emphasize ichthyoplankton collections in the vicinity of the SRP intake canals during 1983-1985.

The ichthyoplankton assemblage in the Savannah River consists of a variety of species which differ in recreational, economic and ecological importance. Among the most abundant ichthyoplankton taxa in the Savannah River are gizzard and/or threadfin shad, American shad, blueback herring, sunfishes, crappie, minnows and suckers (Table C-14). Generally, the clupeids (including anadromous American shad and blueback herring, and resident gizzard and threadfin shad) dominated collections in the Savannah River during 1983-1985. The blueback herring, while somewhat less abundant, is another anadromous species used for commercial purposes in some coastal areas. Some species, such as the largemouth bass and other centrarchids, were comparatively abundant as adults in the Savannah River, but scarce in the ichthyoplankton collections because their eggs and larvae reside in sheltered areas where they are unlikely to become entrained in currents and carried into open water. Such species are less susceptible to SRP entrainment impacts than those that produce drifting eggs and larvae.

BB-3

All clupeid taxa exhibited considerable variation in abundance among years. American shad eggs and larvae increased in relative abundance from 1.4 percent to 50.7 percent of collections between 1983 and 1985. Concurrently, blueback



Source: DOE, 1987

Figure C-6. Map of the Savannah River Showing the Location of the Savannah River Plant, Lower Farfield, Nearfield, and Upper Farfield Sections of the River

Table C-13. Summary of Sampling Locations and Sampling Times for the Savannah River Ichthyoplankton Program^a

River Mile	Year			
	1982	1983	1984	1985
Upper Farfield				
187.1		X	X	X
176.0		X	X	X
166.6		X	X	X
Nearfield				
157.3	X	X	X	X
157.1 ^b	X	X	X	X
157.0	X	X	X	X
155.4	X	X	X	X
155.3 ^b	X	X	X	X
155.2	X	X	X	X
152.2		X	X	X
152.0		X	X	X
150.8	X	X	X	X
150.4	X	X	X	X
145.7				X
141.7		X	X	X
141.5	X	X	X	X
137.7		X	X	X
129.1		X	X	X
128.9		X	X	X
Lower Farfield				
120.0		X	X	X
110.0		X	X	X
97.5		X	X	X
89.3		X	X	X
79.9		X	X	
69.9		X	X	
60.0		X	X	
50.2		X	X	
40.2		X	X	
29.6		X	X	
Duration	March -August	February -July	February -July	February -July
Frequency	Biweekly	Weekly	Weekly	Weekly

BB-3

a. Source: DOE, 1987.

b. SRP Intake Canals

Table C-14. Percent Composition of Fish Eggs and Larvae Collected in the Savannah River, 1983-85^a

Taxa	1983 ^b	1984 ^{b, c}	1985 ^{c, d}
American shad	1.4	14.0	50.7
Blueback herring	12.1	4.5	2.2
Gizzard and/or threadfin shad	19.9	10.8	9.9
Unid. clupeid	6.7	7.6	3.3
Striped bass	0.2	3.0	5.4
Spotted sucker	5.0	4.3	8.1
Unid. sucker	0.8	0.7	0.4
Pirate perch	8.0	0.3	0.1
Yellow perch	3.5	1.1	0.2
Darter	2.6	2.7	0.7
Sunfish			
(Lepomis)	2.1	6.9	0.7
Unid. sunfish	1.1	4.0	0.3
Crappie	16.6	13.5	0.3
Mudminnow	<0.1	<0.1	0.0
Swampfish	<0.1	<0.1	<0.1
Minnow (Cyprinid)	14.0	13.5	3.7
Carp	3.6	3.2	4.6
Mosquitofish	<0.1	<0.1	<0.1
Topminnow		<0.1	<0.1
Needlefish	<0.1	0.1	<0.1
Silverside	0.2	0.2	0.1
Catfish and/or bullhead	0.1	<0.1	0.1
Pickereel	0.3	0.1	<0.1
Sturgeon	<0.1	<0.1	0.1
Gar	<0.1	<0.1	0.0
Unidentified	1.7	9.8	9.2
Total numbers	36,941	18,267	22,698

a. Source: DOE, 1987.

b. Based on 26 transects between RM 29.6 and 187.1.

c. Does not include intake canals.

d. Based on 21 transects between RM 89.3 and 187.1.

herring decreased from 12.1 percent (1983) to 2.2 percent (1985) of collections. Gizzard and/or threadfin shad relative abundance paralleled the decline in blueback herring.

Some of the decline in the relative abundance of blueback herring from 1984 to 1985 could be attributable to the reduction of sampling effort in the lower reaches of the Savannah River, because this section of the river appears to be a major spawning area for the species (Table C-15a). However, the decrease in density from 1983 through 1985 was also observed in the mid-reaches of the

Table C-15a. Mean Ichthyoplankton Densities (No./1000 m³) at Savannah River Transects During February-July 1983.^a

River mile	American shad	Blueback herring	Striped bass	Other shad ^b	Minnows	Sunfish	Crappie	Total Ichthyoplankton ^c
LOWER FARFIELD								
29.6	5.3	11.7	2.7	8.3	4.8	1.5	13.6	67.8
40.0	4.5	16.1	1.4	17.2	6.1	1.1	15.6	89.2
50.2	6.4	20.8	0.5	21.3	12.1	1.9	21.0	118.1
60.0	7.1	32.4	5.1	18.7	11.8	3.4	26.8	144.0
69.9	4.7	19.7	0.5	20.1	6.1	2.0	12.1	87.2
79.9	4.5	26.9	0.8	40.7	6.3	2.0	16.9	124.9
89.3	7.6	32.7	2.3	59.2	9.0	2.4	25.4	171.5
97.5	12.3	39.2	1.1	54.1	10.9	2.6	29.8	191.1
110.0	18.3	13.4	1.3	15.7	17.7	2.5	21.7	136.6
120.0	8.2	8.6	11.3	7.7	12.8	3.0	16.4	98.7
NEARFIELD								
128.9	5.4	5.9	0.7	5.4	14.9	4.7	16.3	84.4
129.1	6.9	5.8	4.1	5.3	18.1	4.2	16.2	95.2
137.7	10.0	3.8	0.1	3.7	22.3	7.5	15.5	105.1
141.5	6.8	4.2	0.0	4.2	14.7	9.7	13.7	102.2
141.7	12.1	4.0	0.0	4.9	12.2	10.1	14.9	110.2
150.4	8.7	2.5	1.3	4.3	12.9	1.7	5.5	54.0
150.8	8.9	3.6	0.1	4.9	11.1	0.9	7.8	53.2
152.0	7.8	1.9	2.4	6.9	12.1	1.7	5.9	62.1
152.2	10.5	2.5	10.2	8.0	14.7	1.1	6.1	90.3
155.2	11.9	1.9	5.1	9.5	12.2	0.3	4.3	65.4
155.3 ^d	0.8	6.5	0.0	33.1	5.9	1.1	9.3	76.8
155.4	10.5	2.6	5.9	11.9	19.2	0.2	6.0	82.3
157.0	12.9	2.9	0.0	8.7	8.3	0.5	6.1	61.5
157.1 ^d	1.0	7.9	0.1	23.7	4.4	1.9	11.9	71.5
157.3	17.8	1.7	0.0	9.6	12.1	1.0	5.4	73.6
UPPER FARFIELD								
166.6	25.6	2.4	6.3	24.7	11.8	2.0	3.7	96.6
176.0	8.9	1.3	0.1	12.8	11.7	1.0	2.9	52.5
187.1	1.6	0.3	0.0	25.2	4.9	0.9	0.7	47.7

a. Source: DOE, 1987.

b. Gizzard and/or threadfin shad.

c. Totals include taxa shown plus taxa not shown.

d. Intake canals.

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river (Tables C-15b and C-15c), and is more likely related to variations in spawning stock abundance or the availability of spawning sites. Low river water levels, especially during the 1985 spawning season, likely reduced access to swamp and backwater spawning sites used by blueback herring (Paller et al., 1986). The sharp increase in American shad ichthyoplankton abundance from 1983 to 1985 may be related to variations in spawning stock abundance.

Striped bass spawning in the upper reaches of the Savannah River had not been documented prior to 1982 (ECS, 1982). Dudley et al. (1977) reported that striped bass spawning was restricted to the lower reaches of the river and McFarlane et al. (1978) collected no striped bass ichthyoplankton during their sampling in 1977. However, striped bass eggs and/or larvae were collected during each year of the Comprehensive Cooling Water Study (Table C-14), and the highest densities occurred between approximately RM 166 to RM 120 during 1983-1985 (Tables C-15a, C-15b and C-15c). Although total striped bass ichthyoplankton abundance was substantially lower than found for American shad, striped bass showed a similar trend in abundance with a substantial increase from 1983 to 1985.

Ichthyoplankton relative abundance and densities for many of the abundant resident fish taxa (e.g., gizzard and/or threadfin shad, pirate perch, crappie and minnows) declined from 1983 to 1985 (Tables C-14, C-15a, C-15b, and C-15c). Suckers exhibited a slight increase and sunfish ichthyoplankton relative abundance was somewhat higher in 1984 than in either 1983 or 1985.

Sturgeon larvae were collected from the Savannah River in the vicinity of the SRP during 1982. Examination of these specimens indicated that both Atlantic sturgeon and the endangered shortnose sturgeon were present (Table C-16). Both sturgeon species have been collected in all subsequent years. Although total sturgeon larvae collections (number of specimens) were highest in 1982, sampling intensity was lowest (Table C-13). Generally, it appears that both species spawn upstream or near the SRP and that shortnose sturgeon spawn earlier and at cooler water temperature than Atlantic sturgeon.

Atlantic and shortnose sturgeon are demersal in nature. Consequently, most larvae were collected in samples near the river bottom. The National Marine Fisheries Service had previously concurred with DOE's determination that the population of shortnose sturgeon in the Savannah River would not be adversely affected by SRP operations (Oravetz, 1983).

Ichthyoplankton Abundance in the Mouths of Savannah River Tributaries - Twenty-seven creeks, ranging from small intermittent streams to major tributaries, were sampled for ichthyoplankton from February through July 1983. Five of these creeks - Beaver Dam Creek, Upper and Lower Three Runs Creeks, Four Mile Creek, and Steel Creek - drain portions of the Savannah River Plant. Researchers collected 5714 larvae and 1423 eggs from all the streams during 1983 (Table C-17).

TE Streams accounted for 8.8 and 14.4 percent of the fish eggs and larvae, respectively. Ninety-four percent of all eggs collected were from Spirit Creek (1230) and Steel Creek (103) (Table C-17). The high number of fish eggs collected at Spirit Creek were threadfin or gizzard shad, taken during May and June. Clupeids were the numerically dominant taxa in all streams; however, crappie, centrarchids, and yellow perch were also important.

Table C-15b. Mean Ichthyoplankton Densities (No./1000 m³) at Savannah River Transects During February-July 1984.^a

River mile	American shad	Blueback herring	Striped bass	Other shad ^b	Minnows	Sunfish	Crappie	Total Ichthyo-plankton ^c
LOWER FARFIELD								
29.6	1.2	0.7	0.0	2.1	1.0	8.3	5.5	24.5
40.0	1.3	0.8	0.0	2.8	0.9	9.1	8.4	30.8
50.2	1.7	0.9	0.0	3.2	2.7	12.6	4.8	32.5
60.0	1.3	2.4	0.0	4.4	1.9	6.1	10.3	33.0
69.9	0.8	0.9	0.0	3.9	3.1	3.2	5.3	24.2
79.9	1.5	2.6	0.0	4.2	2.3	1.8	4.1	25.2
89.3	3.8	1.6	0.6	4.7	4.3	2.5	3.9	30.2
97.5	6.2	4.1	0.7	11.3	3.1	4.0	5.1	44.8
110.0	10.5	1.3	1.6	1.1	5.2	4.6	3.9	35.8
120.0	5.6	1.7	4.1	2.5	5.8	3.2	3.6	34.9
NEARFIELD								
128.9	3.6	0.9	3.7	2.1	6.6	3.4	3.1	32.3
129.1	5.2	0.9	3.1	1.3	7.8	5.1	2.8	34.3
137.7	8.0	1.1	6.4	1.7	9.6	6.4	4.1	49.0
141.5	7.4	2.2	3.4	2.1	13.6	10.0	6.7	57.1
141.7	11.2	1.0	14.3	2.5	12.1	10.4	6.4	67.6
150.4	2.8	3.1	6.7	3.8	5.2	2.7	6.0	41.4
150.8	5.8	2.9	5.2	4.5	4.8	1.7	5.8	39.7
152.0	5.8	1.6	2.1	4.8	4.4	1.5	6.4	34.7
152.2	9.8	1.1	2.8	3.5	5.1	0.9	4.5	38.6
155.2	5.6	1.9	6.1	3.7	3.8	0.6	4.9	35.5
155.3 ^d	0.2	6.6	1.6	4.9	3.0	0.8	10.9	43.1
155.4	4.0	1.1	6.1	3.8	4.2	1.0	5.9	36.8
157.0	9.9	1.5	4.0	3.5	4.6	1.9	6.1	45.3
157.1 ^d	0.2	4.6	1.4	5.2	2.4	1.9	10.1	42.5
157.3	11.8	2.6	3.2	4.0	6.5	1.7	4.6	47.4
UPPER FARFIELD								
166.6	3.3	2.5	0.0	8.2	5.6	0.4	1.1	28.7
176.0	4.0	0.8	0.0	7.0	6.1	1.1	0.3	26.2
187.1	3.6	0.2	0.1	4.0	5.7	0.9	0.4	23.6

a. Source: DOE, 1987.

b. Gizzard and/or threadfin shad.

c. Totals include taxa shown plus taxa not shown.

d. Intake canals.

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Table C-15c. Mean Ichthyoplankton Densities (No./1000 m³) at Savannah River
Transects During February-July 1985.^a

River mile	American shad	Blueback herring	Striped bass	Other shad ^b	Minnows	Sunfish	Crappie	Total Ichthyo- plankton ^c
LOWER FARFIELD								
89.3	47.4	0.9	2.0	2.2	2.5	1.4	0.1	67.8
97.5	26.6	1.7	1.2	4.7	1.6	0.2	0.1	44.1
110.0	39.6	0.6	1.5	1.2	3.2	0.2	0.1	55.6
120.0	35.3	0.8	1.3	1.7	2.2	0.7	0.4	51.7
NEARFIELD								
128.9	41.7	1.4	5.3	2.2	4.1	1.0	0.2	64.2
129.1	31.3	0.8	6.3	1.9	2.9	1.4	0.2	54.7
137.7	34.1	1.8	0.4	2.9	1.9	1.4	0.1	55.2
141.5	30.0	1.4	0.1	3.4	1.5	1.1	0.1	50.9
141.7	54.6	0.9	0.5	3.7	1.8	1.8	0.3	83.2
145.7	63.2	0.7	0.6	3.0	1.6	1.5	0.5	84.3
150.4	22.0	1.0	2.4	2.1	0.8	0.2	0.3	44.7
150.8	12.6	1.9	0.3	3.0	1.0	0.1	0.0	31.8
152.0	10.6	1.4	3.7	3.2	1.6	0.1	0.1	28.7
152.2	14.2	2.2	3.3	3.6	2.0	0.1	0.1	43.1
155.2	18.2	2.6	16.0	3.1	1.0	0.0	0.2	67.1
155.3 ^d	0.3	0.9	2.5	7.0	1.0	0.1	0.2	30.7
155.4	19.3	0.8	13.6	4.8	1.6	0.1	0.0	57.0
157.0	24.6	0.4	0.5	3.8	1.7	0.2	0.1	47.5
157.1 ^d	0.8	1.1	0.1	3.0	0.7	0.2	0.1	22.2
157.3	36.0	0.5	2.1	3.8	1.6	0.2	0.2	81.6
UPPER FARFIELD								
166.6	59.4	3.2	10.7	22.3	2.5	0.2	0.1	149.3
176.0	15.7	2.4	0.1	27.2	4.5	0.4	0.2	70.9
187.1	3.3	2.8	0.1	22.7	5.4	0.6	0.4	58.6

a. Source: DOE, 1987.

b. Gizzard and/or threadfin shad.

c. Totals include taxa shown plus taxa not shown.

d. Intake canals.

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Table C-16. Larval Sturgeon Collected From the Savannah River During 1982, 1983, 1984, and 1985^a

1982						1983					
Collection date	River mile	Sample location ^b	Identity ^c	River temp. (°C)	River Elev. (ft) ^d	Collection date	River mile	Sample location ^b	Identity ^c	River temp. (°C)	River elev. (ft) ^d
3/12	157.3	CT	Sh	12.5	85.9	3/09	79.9	WB	Sh	16.0	94.9
3/26	157.3	CB	Sh	13.2	84.2	3/22	155.4	CB	Sh	12.5	91.9
4/21	150.8	CB	Atl	17.8	83.5	3/22	157.1 ^e	WT	Sh	11.5	92.5
4/22	155.2	EB	Atl	15.2	86.3	3/22	155.3 ^e	ET	Sh	11.5	92.5
4/22	155.2	ET	Atl	15.2	86.3	3/22	155.2	ET	Sh	11.3	92.5
4/22	155.2	EB	Atl	15.2	86.3	3/23	97.5	WT	Sh	12.6	92.5
4/22	157.0	WB	Atl	15.2	86.3	3/29	155.2	CT	Atl	12.5	90.6
4/22	157.0	EB	Atl	15.3	86.3	4/26	129.1	CB	Atl	14.4	94.0
5/21	155.4	CB	Atl	20.3	83.2	5/03	157.0	WB	Atl	18.1	86.5
5/21	155.4	CB	Atl	20.3	83.2	5/10	155.4	CB	Atl	17.5	84.5
5/21	157.0	CB	Atl	20.2	83.2	5/17	150.4	EB	Atl	22.5	84.3
5/21	157.3	CT	Atl	20.2	83.2	5/18	69.9	EB	Atl	21.5	84.6
5/21	157.3	CB	Atl	20.2	83.2	6/14	150.8	CB	Atl	20.5	83.8
8/21	157.3	CT	Atl	21.0	84.7						
1984						1985					
Collection date	River mile	Sample location ^b	Identity ^c	River temp. (°C)	River Elev. (ft) ^d	Collection date	River mile	Sample location ^b	Identity ^c	River temp. (°C)	River elev. (ft) ^d
3/28	120.0	EB	Sh	15.0	89.3	3/19	155.4	WB	Sh	12.0	83.6
4/04	110.0	CB	Sh	15.5	88.6	3/26	166.6	EB	Sh	12.8	83.3
4/23	176.0	WB	Atl	14.0	92.9	4/09	157.3	EB	Atl	14.1	83.3
4/24	152.0	CB	Atl	14.5	93.3	4/16	141.7	EB	Atl	16.5	83.3
5/02	176.0	WB	Atl	15.8	94.5	4/16	157.0	WB	Atl	16.0	83.3
5/23	110.0	WB	Atl	20.5	86.6	4/24	120.0	CB	Atl	20.5	84.1
5/29	157.0	WB	Atl	20.4	86.1	4/30	176.0	WT	Atl	18.6	82.8
5/29	152.2	WB	Atl	20.5	86.1						
5/29	152.2	EB	Atl	20.5	86.1						

a. Source: DOE, 1987.

b. Samples were taken in mid-channel (C), near the South Carolina bank (E), and near the Georgia bank (W); samples were also taken near the top (T) and near the bottom (B) of the water column.

c. Sh = shortnose sturgeon; Atl = Atlantic sturgeon.

d. River elevation at Jackson, SC.

e. Intake canal.

Table C-17. Ichthyoplankton Abundance in 27 Savannah River Tributaries Located Between RM 30 and 187.2. February - July 1983^a

Creek, RM	Mean discharge (m ³ /sec)	Number dates sampled	Larvae collected	Eggs collected	Taxa collected	Mean ichthyo-plankton density (no./1000 m ³)	Maximum density (no./1000 m ³)	Date of maximum density	Dominant taxa on date of max. density	Number ^b ichthyoplankton transported x 10 ⁶
Collin, 30.0	195.5	22	238	0	14	49	225	03/18	Blueback herring crappie	180.2
Meyers, 35.4	150.1	16	155	0	15	42	185	05/05	Unidentified clupeid	157.6
Coleman Lake, 40.3	237.9	22	309	1	13	62	266	03/18	Blueback herring crappie	341.9
Lockners, 43.2	24.8	20	238	0	14	126	500	07/08	Sunfish	81.1
Ebenezer, 44.8	36.9	23	502	5	15	105	802	03/18	Crappie	53.3
Seines Landing, 47.7	1.2	11	70	2	14	194	1145	05/12	Yellow perch	1.1
Plank, 51.1	8.7	6	86	0	8	105	195	06/30	Other shad	9.4
Lake Parachuchia, 64.2	79.6	18	653	9	14	263	738	03/24	Blueback herring	279.2
Black, 78.4	6.4	4	5	1	4	29	49	03/17	Blueback herring pirate perch	3.4
Pike, 84.1	30.1	17	112	0	11	77	377	07/27	Sunfish	30.8
Ware, 88.6	1.4	2	50	0	7	664	1093	05/25	Carp	4.5
Buck, 92.6	28.1	20	708	13	16	383	2669	05/11	Blueback herring	185.3
Briar, 97.6	86.4	23	760	3	15	140	938	04/13	Blueback herring unidentified clupeid	220.7
The Gaul, 109.0	6.7	3	34	0	9	75	100	04/26	Blueback herring	1.3
Smith Lake, 126.5	48.5	22	329	5	14	90	712	04/12	Crappie	148.1
Lower Three Runs, 129.0	2.7	10	72	0	12	187	1698	05/03	Crappie	2.1
Sweetwater, 133.5	33.4	13	102	4	14	51	194	05/03	Pirate perch	19.9
Lower Boggy Gut, 141.3	4.2	3	7	1	5	17	43	03/15	Crappie	0.1
Steel, 141.6	26.2	24	518	103	14	123	507	04/05	Blueback herring	77.2
Four Mile, 150.6	4.1	16	40	7	11	50	332	04/05	Blueback herring	2.7
Beaver Dam, 152.1	8.3	13	138	10	10	74	320	05/03	Yellow perch	7.4
Upper Three Runs, 157.2	15.8	19	56	5	10	25	334	05/03	Crappie, yellow perch	2.4
Upper Boggy Gut, 162.2	9.5	9	32	2	9	43	116	06/08	Sunfish	2.2
McBean, 164.2	5.1	5	78	1	11	93	186	07/07	Other shad	6.3
Hollow, 176.1	14.5	16	107	21	13	53	229	03/22	Crappie	34.4
Spirit (183.3)	8.6	19	300	1230	13	157	4412	06/02	Other shad	38.0
Butler, 187.2	13.3	9	15	0	4	37	185	05/12	Minnow	4.4

a. Source: Du Pont, 1985

b. Calculated as sum of ichthyoplankton density x creek discharge for each sampling data extrapolated to intervals between sampling dates.

The number of ichthyoplankters transported from creek to river ranged from approximately 0.1×10^6 from Lower Boggy Gut to 342×10^6 from Coleman Lake (Table C-17). Steel Creek and Beaver Dam Creek accounted for 77.2×10^6 and 7.5×10^6 ichthyoplankters, respectively, the greatest production of any of the SRP streams. Some creeks exhibited high densities but low transport numbers due to their low discharge rates.

Considerably more fish spawning occurred in Four Mile Creek in 1983 than in 1982, apparently due to unusually high river levels that reversed stream flow and lowered water temperatures enough to allow fish to enter the creek and from the transport of ichthyoplankton from nearby refuge areas into the creek when river levels receded. Centrarchids, blueback herring, and shad dominated the larval catch. Ichthyoplankton densities were low to moderate in March, peaked at 332 per 1000 cubic meters on April 4, and declined to zero by early June (Table C-17). Larvae collected during May were taken at temperatures between 35° and 37°C and represent larvae transported from refuge spawning areas in the Four Mile Creek watershed. Although more ichthyoplankton were collected in 1983, similar medium-sized streams had higher densities and longer spawning periods. The mean temperature in these creeks was often as much as 15°C lower than that in Four Mile Creek. Apparently, the elevated temperatures in this stream limited spawning. Transport of ichthyoplankton from Four Mile Creek was very low (2.7×10^6), ranking it as twenty-first of the 27 streams sampled (Table C-17).

During sampling trips, researchers collected 138 fish larvae and 10 fish eggs on Beaver Dam Creek (Table C-17). Sunfish, silversides, and yellow perch dominated species composition. Because of excessively high river levels, Beaver Dam Creek was not sampled during February, March, or most of April. Subsequent sampling indicated a peak density of 320 per 1000 cubic meters (primarily sunfish) in early May, which declined to low densities by July. Similar-sized streams had higher densities, mainly because of high shad concentrations. Temperatures in Beaver Dam Creek were generally 3° to 7°C higher than in similar-sized creeks. Although elevated temperatures might have reduced spawning later in the year in Beaver Dam Creek, the effect was not as pronounced as that in Four Mile Creek. The number of ichthyoplankters transported from Beaver Dam Creek (7.4×10^6) was equivalent to or greater than from other creeks that did not have large numbers of threadfin or gizzard shad.

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Effects of Cooling Water Intakes

The once-through cooling water systems for C- and K-Reactors each withdraw about 11 cubic meters of water per second from the Savannah River through the 1G and 3G pumphouses. An additional 1 cubic meter per second enters these intakes to provide makeup water for P-Area. The 5G pumphouse provides cooling water to the D-Area powerhouse at about 3 cubic meters per second. The current combined cooling water flow requirement for these facilities is about 26 cubic meters per second. This withdrawal of river water could affect the fishes inhabiting areas on or adjacent to the Savannah River Plant in two ways:

- Entrainment of fish eggs and larvae through the cooling water system
- Impingement of larger fishes on the intake screens

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Estimates of the impacts of entrainment and impingement are based on field data collected during past and present sampling programs performed in the SRP vicinity (Du Pont, 1985; Paller, O'Hara, and Osteen, 1985; Paller and Osteen, 1985). The following sections discuss the results of these investigations as summarized in DOE (1987).

Entrainment - The entrainment of fish eggs and larvae (ichthyoplankton) at intake structures is affected by a variety of factors including overall ichthyoplankton abundance in waters adjacent to the intake and percentage of river water withdrawn. The total magnitude and species composition of entrainment can also be influenced by aspects of intake design, the spatial distribution of ichthyoplankton relative to the intakes, and fish species behavioral and life history characteristics. The ultimate result of entrainment-related mortality on fish population persistence depends on the magnitude of species-specific mortality rates and the population level responses of the species to this added source of mortality.

Entrainment of ichthyoplankton into the SRP cooling water intake pumps removes them from the Savannah River population. Entrainment of ichthyoplankton is dependent on several factors including the density of organisms in the river, the amount of spawning in the intake canals, the volume of water withdrawn by each pump and, in the case of 1G intake, the density of organisms in Upper Three Runs Creek which enters the river immediately upstream of the 1G intake canal (Figure 2-1).

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When fish larvae enter the intake canals from the river, they move from rapid currents to slow currents which may enable larger larvae to swim to protected shoreline areas. This behavior could reduce the mortality rate of larvae entrained from the river. However, there is evidence from the larval collections made during 1982 (ECS, 1983) that the intake canals are used as spawning sites by several species. Accordingly, loss of larvae for some species by entrainment may be greater than is indicated by the ichthyoplankton densities in the river water entering the canal. Consequently, larval entrainment at the 1G and 3G intakes was calculated using the larval density in the intake canals since these organisms are the ones most likely to be lost from the total Savannah River ichthyoplankton population, regardless of whether they were spawned in the canal or moved in on river currents. Larval densities in the Savannah River were used to calculate entrainment at the 5G intake because of the short length of this canal.

The calculation of entrainment of fish eggs from the Savannah River into the three pumphouses was not as direct as the calculation of larval entrainment. Few eggs were actually collected in the canals. Generally, fish that spawn in freshwater have demersal rather than planktonic eggs. The only exceptions in the Savannah River drainage are the anadromous American shad and striped bass. The reduced current velocity in the intake canals allows the suspended eggs to settle out of the water column (McFarlane, 1982). Silt settles over these eggs and they die. The entrainment losses were calculated such that fish eggs that settle out of the water column and those actually entrained by the pumps are assumed to be lost. Consequently, the average egg densities used in the entrainment calculations were from the immediate upstream river transect. The egg densities for 3G and 5G are the same because they were calculated from the river transect immediately upstream of the 3G intake canal.

The density of eggs entering 1G canal was not calculated directly from the upstream river transect because a portion of the water entering 1G canal comes from Upper Three Runs Creek. The relative percent contribution of Upper Three Runs Creek and the river to the 1G intake canal water was estimated by measuring the sodium concentrations in the river upstream of the 1G canal, in Upper Three Runs Creek, and in the mixed water coming out of the pump. These percentages were multiplied by the density of eggs from each source to get an average density of fish eggs entering the 1G canal.

To estimate total entrainment of ichthyoplankton during a spawning season, the daily entrainment rates were multiplied by the number of days between samples, generally a week, and summed. Annual entrainment is considered to be equal to that which occurs during the February-July spawning season. There is generally very little ichthyoplankton in the river to be entrained from September to January.

A minimum of 17 species of larval fishes were entrained at the three intake structures at the SRP during 1983 (Table C-18). Because larval fish are difficult to identify, there were probably unidentified species in these collections. The most abundant family of fish collected was Clupeidae, the herring family, which comprised 59 percent of the total ichthyoplankton entrainment. The single most abundant taxon was the genus Dorosoma (gizzard shad and threadfin shad), with 10.5×10^6 larvae (37.4 percent). Other abundant taxa were crappie, blueback herring and minnows, which represented 14.1, 9.5 and 9.0 percent, respectively.

Total larval fish entrainment for the SRP from February-July 1983 was calculated to be 28.0×10^6 , of which 12.9×10^6 larvae (46.2 percent) were from the 1G pumphouse, 13.2×10^6 larvae (47.3 percent) were from the 3G pumphouse and 1.8×10^6 (6.5 percent) were from the 5G pumphouse (Table C-19).

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BD-5

At least 17 taxa of larval fish were entrained at the SRP pumphouses during the 1984 spawning season (Table C-20). As in 1983, the most common family found in the entrainment samples was Clupeidae, the herring and shad family, which comprised 50 percent of the larval fish that were entrained. The single most abundant taxon was crappie with 4.3×10^6 larvae (24.5 percent). Other abundant taxa were unidentified clupeids, blueback herring, and other shad (gizzard and/or threadfin shad), which comprised 23.9, 13.2 and 12.7 percent of the total larvae entrained, respectively. Generally, there were no differences in the species composition among the three pumphouses.

Total larval fish entrainment for the SRP from February to July 1984 was calculated to be 17.6×10^6 . The 1G pumphouse entrained 7.7×10^6 larvae (44 percent), 8.8×10^6 larvae (50.3 percent) were entrained at the 3G pumphouse and 1.0×10^6 larvae (5.6 percent) at the 5G pumphouse (Table C-19).

At least 6 taxa of larvae were entrained at the SRP pumphouses in 1985 (Table C-21). The most common larval fish entrained were suckers, which comprised 43 percent of the larval fish entrained. The single most abundant taxon was spotted sucker with a total of 4.6×10^6 larvae (42.7 percent) entrained at the three pumphouses. Other abundant taxa were gizzard and/or

Table C-18. Estimated Number and Percent Composition of Larval Fish
Entrained at 1G, 3G, and 5G Pumphouses, February-July 1983^a

Taxa	Pumphouse				Percent Composition
	1G (x1000)	3G (x1000)	5G (x1000)	Total (x1000)	
Clupeidae					
American shad	90	80	4	174	0.6
Blueback herring	1434	1146	68	2648	9.5
Other shad	4315	5782	365	10,462	37.4
Unident. clupeids	1641	1572	90	3303	11.8
Esocidae					
Unident. pickerel	129	53	9	191	0.7
Cyprinidae					
Carp	26	80	17	123	0.4
Unident. cyprinids	814	1026	690	2530	9.0
Catostomidae					
Spotted sucker	853	573	237	1663	5.9
Other suckers	-	13	20	33	0.1
Ictaluridae					
Unident. catfish	-	13	-	13	<0.1
Aphredoderidae					
Pirate perch	388	400	28	816	2.9
Atherinidae					
Brook silverside	-	-	7	7	<0.1
Percichthyidae					
Striped bass	13	-	2	15	<0.1
Centrarchidae					
Unident. crappie	2170	1599	184	3953	14.1
Unident. sunfish	233	40	2	275	1.0
Other centrarchids	129	133	7	269	1.0
Percidae					
Yellow perch	142	320	33	495	1.8
Other percids	388	187	52	627	2.2
Other	129	213	26	368	1.3
Total	12,894	13,230	1,841	27,965	100.0

a. Source: DOE, 1987.

Table C-19. Estimated Entrainment of Larval Fish at SRP Intakes^a

		1G	3G	5G	Total
1977 ^b	Number ($\times 10^6$)	7.1	11.9	0.6	19.6
	Percent	36.2	60.7	3.1	
1982 ^c	Number ($\times 10^6$)	5.2	12.0	0.7	17.9
	Percent	28.8	67.1	4.0	
1983 ^d	Number ($\times 10^6$)	12.9	13.2	1.8	28.0
	Percent	46.2	47.3	6.5	
1984 ^e	Number ($\times 10^6$)	7.7	8.8	1.0	17.6
	Percent	44.0	50.3	5.6	
1985 ^f	Number ($\times 10^6$)	3.8	6.4	0.7	10.9
	Percent	34.9	58.7	6.4	
Average number ($\times 10^6$)		8.1	9.5	1.2	18.8
(1983-85) percent		43.4	50.3	6.3	

a. Source: DOE, 1987.

b. April-June, McFarlane et al. (1978).

c. March-August, ECS (1983).

d. February-July, Paller et al. (1984).

e. February-July, Paller et al. (1985).

f. February-July, Paller et al. (1986).

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threadfin shad (22.0 percent), unidentified Clupeidae (11.4 percent), and carp (10.3 percent). Generally, there were no substantive differences in the species composition between the three pumphouses.

Total larval fish entrained due to SRP activities from February-July 1985 was calculated to be 10.9×10^6 (Table C-19). The 1G pumphouse entrained 3.8×10^6 larvae (35 percent); 6.4×10^6 larvae (59 percent) were entrained at the 3G pumphouse and 0.7×10^6 larvae (6 percent) at the 5G pumphouse.

For the five years for which data are available, estimated entrainment of larval fish was highest in 1983 when 28.0×10^6 larvae were entrained (Table C-19). Minimum larval entrainment (10.9×10^6 larvae) occurred in 1985. The 1983 estimated larval entrainment is almost 50 percent higher than the average entrainment (18.8×10^6 larvae) for the three year period (1983-85) during which sampling methodologies were consistent. The 1983-85 average entrainment is comparable to entrainment estimates for 1977 and 1982.

The highest percentage of larval entrainment occurred at the 3G intake during 1983-85 (9.5×10^6 larvae, 50.3 percent of total; Table C-19). Larval entrainment was substantially lower at the 1G intake (8.1×10^6 larvae, 43.4 percent of total). Larval entrainment at the 5G intake was consistently

Table C-20. Estimated Number and Percent Composition of Larval Fish
Entrained at 1G, 3G, and 5G Pumphouses, February-July 1984^a

Taxa	Pumphouse				Percent Composition
	1G (x1000)	3G (x1000)	5G (x1000)	Total (x1000)	
Clupeidae					
American shad	36	26	—	62	0.4
Blueback herring	891	1398	39	2328	13.2
Other shad	1010	1085	139	2234	12.7
Unident. clupeids	2102	1975	116	4193	23.9
Esocidae					
Unident. pickerel	23	7	—	30	0.2
Cyprinidae					
Carp	175	203	46	424	2.4
Unident. cyprinids	449	679	167	1295	7.4
Catostomidae					
Spotted sucker	495	506	118	1119	6.4
Other suckers	—	23	12	35	0.2
Aphredoderidae					
Pirate perch	—	—	3	3	<0.1
Percichthyidae					
Striped bass	33	73	17	123	0.7
Centrarchidae					
Unident. crappie	1908	2181	233	4322	24.5
Unident. sunfish	147	100	22	269	1.5
Other centrarchids	200	59	16	275	1.6
Percidae					
Yellow perch	77	218	5	300	1.7
Other percids	84	219	39	342	1.9
Lepisosteidae					
Gar	19	—	—	19	0.1
Other	<u>99</u>	<u>87</u>	<u>19</u>	<u>205</u>	<u>1.2</u>
Total	7,748	8,839	991	17,578	100.0

a. Source: DOE, 1987.

Table C-21. Estimated Number and Percent Composition of Larval Fish
Entrained at 1G, 3G, and 5G Pumphouses, February-July 1985^a

Taxa	Pumphouse			Total (x1000)	Percent Composition
	1G (x1000)	3G (x1000)	5G (x1000)		
Clupeidae					
American shad	46	9	5	60	0.6
Blueback herring	195	198	21	414	3.8
Other shad	563	1660	171	2394	22.0
Unident. clupeids	379	797	69	1245	11.4
Cyprinidae					
Carp	341	687	89	1117	10.3
Unident. cyprinids	122	225	61	408	3.8
Catostomidae					
Spotted sucker	1835	2585	223	4643	42.7
Unident. suckers	0	24	6	30	0.4
Others	341	195	39	575	5.1
Total	3,822	6,380	684	10,886	100.1

a. Source: DOE, 1987.

low (1.2×10^6 larvae, 6.3 percent), and never exceeded 6.5 percent of the total entrainment at the SRP river water intakes during 1983-85. Thus, the magnitude of larval entrainment at the SRP is primarily determined by losses at the 1G and 3G intakes.

The relative abundance of larval taxonomic groups entrained varies substantially from year-to-year. McFarlane et al. (1978) reported that clupeids (48 percent), primarily blueback herring (29.1 percent), were most abundant among entrained larvae in 1977. Cyprinid (10.0 percent) and catostomid (11.2 percent) larvae were relatively abundant. No striped bass eggs or larvae were collected during sampling in 1977.

Clupeid larvae also dominated entrainment collections during 1983-85. This group accounted for over 50 percent of larval entrainment in 1983 (Table C-18) and 1984 (Table C-20), but only approximately 38 percent in 1985 (Table C-21). Among the clupeids, gizzard and/or threadfin shad larvae were most abundant, representing 37.3, 12.7 and 22.0 percent of total larval entrainment in 1983, 1984, and 1985, respectively. Blueback herring represented 9.5, 13.2 and 3.8 percent of collections in those years. American shad larvae were a minor component of entrainment, ranging from 0.4 to 0.6 percent of entrainment from 1983-85.

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Abundances of other larval taxa were also variable among years in entrainment. Cyprinids ranged from 9.4 to 14.1 percent of entrained larvae (Tables C-18, C-20, and C-21). However, the greatest change in relative composition occurred among catostomid larvae, with spotted sucker larvae increasing from 5.9 and 6.4 percent of larval entrainment in 1983 and 1984, to 42.7 percent in 1985.

The total egg entrainment during February-July 1983 was calculated to be 9.2×10^6 eggs of which 4.3×10^6 eggs were entrained at 1G, 4.2×10^6 eggs at 3G, and 0.7×10^6 eggs at 5G (Table C-22). The most abundant species was American shad which represented 55.0 percent of the total eggs entrained (Table C-23). The other abundant groups were other eggs and striped bass eggs, representing 28.0 and 14.2 percent of the total egg entrainment, respectively.

The total fish egg entrainment during February-July 1984 was estimated to be 5.8×10^6 eggs, of which 2.7×10^6 eggs (46.6 percent) were entrained at the 1G pumphouse, 2.6×10^6 eggs (45.4 percent) at the 3G pumphouse and 0.5×10^6 eggs (8.0 percent) at the 5G pumphouse (Table C-22). The most abundant egg species was American shad, representing 50.3 percent of the total eggs entrained (Table C-23). The other abundant groups of eggs entrained were striped bass and other eggs, representing 30.6 and 15.2 percent of the total eggs entrained, respectively.

BB-3 The total fish egg entrainment during February-July 1985 was estimated to be
BD-5 15.1×10^6 , of which 7.8×10^6 eggs (51.4 percent) were entrained at the 1G pumphouse, 6.2×10^6 (41.4 percent) at the 3G pumphouse, 1.1×10^6 eggs (7.3 percent) at the 5G pumphouse (Table C-22). American shad eggs were most abundant in entrainment and represented 46.7 percent of the total eggs entrained (Table C-23). The other abundant groups of eggs entrained were striped bass and other eggs, representing 26.2 percent and 24.8 percent of the total entrained, respectively.

Total fish egg entrainment varied considerably among the years for which data are available. Average total entrainment from 1983-85 was 10.0×10^6 eggs at the three SRP intakes (Table C-22). However, egg entrainment varied almost threefold during those years from 5.8×10^6 in 1984 to 15.1×10^6 in 1985. The highest estimated egg entrainment occurred in 1982 (18.1×10^6), while estimated entrainment in 1977 (6.9×10^6) was near the low end of the range of values.

The proportions of total eggs entrained at each of the three intakes remained relatively constant from year to year. Highest egg entrainment occurred at the 1G intake during all years except 1977 when entrainment was highest at the 3G intake (Table C-22). The 1G intake averaged 49.1 percent of the total eggs entrained from 1983 to 1985. The 3G intake averaged 43.3 percent of total egg entrainment from 1983 to 1985, while the 5G intake averaged 7.6 percent of egg entrainment during this period.

American shad eggs dominated entrainment collections from 1983 to 1985 and the percentage of total egg entrainment attributable to this species was relatively constant (Table C-23). American shad eggs averaged 50.0 percent of egg entrainment and ranged from 46.7 percent (1985) to 55.0 percent (1983) of all eggs entrained. The number of American shad eggs entrained annually varied

Table C-22. Estimated Egg Entrainment at SRP Intakes^a

		1G	3G	5G	Total
1977 ^b	Number (x10 ⁶)	2.4	4.0	0.5	6.9
	Percent	34.8	58.0	7.2	
1982 ^c	Number (x10 ⁶)	8.7	8.2	1.2	18.1
	Percent	48.3	45.1	6.6	
1983 ^d	Number (x10 ⁶)	4.3	4.2	0.7	9.2
	Percent	46.7	45.7	7.6	
1984 ^e	Number (x10 ⁶)	2.7	2.6	0.5	5.8
	Percent	46.6	44.8	8.6	
1985 ^f	Number (x10 ⁶)	7.8	6.2	1.1	15.1
	Percent	51.1	41.1	7.3	
Average number (x10 ⁶)		4.9	4.3	0.8	10.0
(1983-85) percent		48.3	43.8	7.8	

a. Source: DOE, 1987.

b. April-June, McFarlane et al. (1978).

c. March-August, ECS (1983).

d. February-July, Paller et al. (1984).

e. February-July, Paller et al. (1985).

f. February-July, Paller et al. (1986).

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substantially, however, as total egg entrainment varied. The highest number of American shad eggs entrained was 7.1×10^6 in 1985. However, this species represented only 46.7 percent of total egg entrainment that year.

Striped bass eggs were less than half as abundant as American shad eggs in entrainment, averaging 23.4 percent (2.4×10^6 eggs/year) from 1983 to 1985 (Table C-23). However, striped bass eggs varied widely among years both as a percentage of total egg entrainment (14.2 - 30.6 percent) and as numbers of eggs entrained annually (1.3×10^6 - 4.0×10^6 eggs/year). Eggs of blueback herring, *Dorosoma* spp. (gizzard and/or threadfin shad) and percids were relatively minor components in entrainment. The undifferentiated component of other eggs represented a substantial component of egg entrainment, but likely included a wide variety of taxa, few of which represented substantial individual contributions to total egg entrainment.

Ichthyoplankton Withdrawal - The percentage of ichthyoplankton withdrawn from the Savannah River is determined by dividing the number of fish eggs and larvae entrained by the number of eggs and larvae transported past the intake canals in the Savannah River. The number of ichthyoplankton entrained at each intake is derived by summing the numbers of eggs and larvae that were entrained during each year (Table C-24). The number of ichthyoplankton that

Table C-23. Estimated Entrainment and Taxonomic Composition of Fish Eggs at SRP Intakes, 1983-85^a

Taxa		1983 ^b	1984 ^c	1985 ^d	Average
American shad	Number (x10 ⁶)	5.07	2.91	7.06	5.01
	Percent	55.0	50.3	46.7	50.0
Blueback herring	Number (x10 ⁶)	0.09	0.07	0.14	0.10
	Percent	1.0	1.2	0.9	1.0
<u>Dorosoma</u> spp.	Number (x10 ⁶)	- ^e	0.13	0.21	- ^f
	Percent	- ^e	2.2	1.4	- ^f
Striped bass	Number (x10 ⁶)	1.31	1.77	3.96	2.35
	Percent	14.2	30.6	26.2	23.4
Unident. percids	Number (x10 ⁶)	0.16	0.02	- ^e	- ^f
	Percent	1.7	0.3	- ^e	- ^f
Other eggs	Number (x10 ⁶)	2.58	0.88	3.74	2.4 ^g
	Percent	28.0	15.2	24.8	25.6 ^g
Total number (x10 ⁶)		9.21	5.78	15.11	10.03

a. Source: DOE, 1987.

b. Paller et al. (1984).

c. Paller et al. (1985).

d. Paller et al. (1986).

e. Not provided in source document.

f. Not calculated because of partial data.

g. Includes Dorosoma spp. and unident. percids.

were vulnerable to entrainment was estimated by multiplying ichthyoplankton densities in the river near the canals times the river discharge on that date. Ichthyoplankton densities at RM 157.3 were used for entrainment at the 1G intake, and densities at RM 155.4 were used for estimates at the 3G and 5G intakes. Annual ichthyoplankton transport was derived by extrapolating the weekly measurements through the sampling season (February to July).

The total number of ichthyoplankton entrained was consistently highest at the 3G intake and ranged from 11.4 x 10⁶ ichthyoplankton in 1984 to 17.4 x 10⁶ in 1983 (Table C-24). Entrainment at the 1G intake was slightly less than at 3G, while a much smaller number of ichthyoplankton was entrained at the 5G intake.

Total number of ichthyoplankton entrained was highest in 1983, with substantially lower numbers of eggs and larvae entrained in 1984 and 1985 (Table C-24). Total numbers of ichthyoplankton entrained were similar in 1984 and 1985.

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Table C-24. Percentage of Savannah River Ichthyoplankton Entrained at SRP Intakes, 1983-85^a

		1983 ^b	1984 ^c	1985 ^d
Number entrained (x10 ⁶)	1G	17.2	10.4	11.6
	3G	17.4	11.4	12.6
	5G	2.5	1.5	1.8
	Total	37.1	23.3	26.0
Number transported in River (x10 ⁶)	RM 157.3	388	282	212
	RM 155.4	405	216	133
Percent entrained	1G	4.4	3.7	5.5
	3G	4.3	5.3	9.5
	5G	0.6	0.7	1.4
	Total ^e	9.6	8.3	12.3
Percent river withdrawn ^f		7.7	7.0	12.2

a. Source: DOE, 1987.

b. Paller et al. (1984).

c. Paller et al. (1985).

d. Paller et al. (1986).

e. Based on transport at RM 157.3.

f. All intakes combined, February-July.

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Estimates of ichthyoplankton transport varied among years and between transects at which transport was calculated (Table C-24). Highest ichthyoplankton transport occurred during 1983 when densities (Table C-15a) and river discharge (Table C-25) were both relatively high. Ichthyoplankton transport past the SRP intakes was substantially lower in 1984 and 1985. In 1984 ichthyoplankton densities were relatively low (Table C-15b), while river discharge was slightly below that observed in 1983 (Table C-25). Ichthyoplankton densities in 1985 (Table C-15c) were comparable to densities observed in 1983, but river discharge was extremely low as a result of low winter rainfall and relatively low releases of water from Clarks Hill Reservoir.

The combined effects of changes in ichthyoplankton density and river water discharge among years resulted in differences in estimates of the percentages of ichthyoplankton entrained from the river each year (Table C-24). The percentage of ichthyoplankton entrained at all intakes was lowest in 1984 (8.3 percent) and only slightly higher in 1983 (9.6 percent). The highest percentage of river ichthyoplankton entrained was in 1985 (12.3 percent) when Savannah River discharge was low during the spawning season (Table C-25).

The primary factor that appears to influence the percentage of river ichthyoplankton entrained in the SRP intakes is the percentage of river water withdrawn (Table C-24). Although the volume of river water withdrawn by the SRP remained relatively constant during the spawning season among the three

Table C-25. Monthly Average^a Savannah River Discharge (m³/sec)
at the Jackson Gauge, Water Years^b, 1972-85^c

	1972-82			1983 Average	1984 Average	1985 Average ^d	1983-85 Average
	Average	Maximum	Minimum				
October	208.7	247.7	143.6	190.1	173.8	184.1	182.7
November	249.7	410.2	129.2	170.4	164.2	182.7	172.4
December	285.7	395.7	162.4	247.9	258.5	172.3	226.3
January	359.1	461.6	190.8	418.6	366.8	183.6	323.0
February	412.6	533.6	221.9	493.4	403.2	375.5	424.0
March	332.9	529.2	195.4	513.3	469.3	211.8	398.1
April	338.3	561.0	188.1	503.3	412.3	177.9	364.5
May	300.5	394.5	160.9	257.0	396.5	157.7	270.4
June	305.7	560.8	190.0	297.3	250.9	151.5	266.6
July	231.7	391.5	154.8	196.9	234.1	164.8	198.8
August	204.5	241.5	161.1	187.7	343.8	162.1	231.2
September	199.5	232.0	241.5	189.8	216.8	155.4	187.3

a. Average discharge underestimated during high flow, maximum discharge reliably measured is approximately 625 m³/sec, which was used in calculations when discharge exceeded that value.

b. Water Year is October-September, e.g., Water Year 1985 is October 1984-September 1985.

c. Source: DOE, 1987.

d. Source: USGS, 1986.

years (Table C-26), river discharge varied substantially and the percentage of river water withdrawn during the spawning season was higher in 1985 than in 1983 or 1984.

Impingement - Studies to measure and evaluate the loss of fish trapped on the traveling intake screens began in 1977 (McFarlane, Frietsche, and Miracle, 1978). They resumed in March 1982 and continued through 1985 (ECS, 1983; Paller et al., 1984; Paller and Osteen, 1985; Paller and Saul, 1986) as part of the expanded ongoing Savannah River aquatic ecology program. Results of these investigations indicate that several factors, including the number of pumps in operation, the volume of water pumped, the river water level, the

Table C-26. Monthly Volume and Percent of Savannah River Water
Withdrawn at the 1G and 3G Intakes at the SRP, 1983-85^a

		<u>1983</u>	<u>1984</u>	<u>1985</u>
January	Volume (m ³ /sec)	23.7	25.3	23.0
	Percent of River ^b	5.8	5.6	12.9
February	Volume (m ³ /sec)	22.5	15.2	22.8
	Percent of River	4.6	4.1	6.7
March	Volume (m ³ /sec)	22.6	18.0	21.6
	Percent of River	4.4	4.4	10.5
April	Volume (m ³ /sec)	22.8	23.7	21.8
	Percent of River	4.1	6.3	12.4
May	Volume (m ³ /sec)	22.8	23.6	22.8
	Percent of River	9.3	6.4	14.6
June	Volume (m ³ /sec)	16.9	22.0	18.7
	Percent of River	6.4	9.2	12.6
July	Volume (m ³ /sec)	19.5	22.2	15.7
	Percent of River	10.2	9.8	9.5
August	Volume (m ³ /sec)	23.4	23.1	15.3
	Percent of River	12.7	7.8	9.5
September	Volume (m ³ /sec)	22.6	23.8	16.4
	Percent of River	12.1	11.3	10.7
October	Volume (m ³ /sec)	23.1	18.8	19.9
	Percent of River	13.5	10.5	- ^c
November	Volume (m ³ /sec)	22.9	14.4	21.3
	Percent of River	14.4	7.9	--
December	Volume (m ³ /sec)	23.6	22.0	18.2
	Percent of River	9.8	13.1	--

a. Source: DOE, 1987.

b. Percentage overestimated during months of high river discharge.

c. River discharge volume not available.

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water temperature, and the density and species of fish in the intake canal, influence the impingement rate to some degree.

Impingement data were summarized from the reports prepared on these investigations (DOE, 1987). Although impingement samples were collected from March 1982 to September 1985, the samples used in this evaluation are primarily from September 1982 through September 1985 because methodologies

were consistent during this interval. Additional unpublished data from October to December 1985 were included as appropriate.

In a preliminary biological measurement program, collections of impinged fishes on the traveling screens at the 1G, 3G, and 5G intakes were made biweekly between April and August 1982. Between September 1982 and August 1985 collections were made on approximately 100 randomly selected sampling dates yearly. The data collected after August 1982 more accurately represent impingement over an annual cycle because the frequency of collection was higher and more consistent.

Impingement at 1G and 3G intakes varied substantially each year. The maximum annual impingement collections occurred at the 1G intake in 1983 (1462 fish, Table C-27). By extrapolating the estimated daily impingement for 1983, it is estimated that 5336 fish were impinged at the 1G intake per year. The highest annual impingement collections at the 3G (1150 fish) and 5G (1282 fish) intakes also occurred in 1983 with an estimated annual impingement of 4198 and 4679 fish per year, respectively. Although the sampling effort remained constant from 1983 through 1985, both the actual (measured) impingement and the estimated annual impingement declined at the 1G and 3G intakes. The minimum estimated annual impingement occurred in 1985 at the 1G (1670 fish) and 3G (1316 fish) intakes; minimum annual impingement occurred in 1984 at the 5G intake (213 fish). Average estimated annual impingement for the three year period was 3124 fish (8.56 fish/day) at the 1G intake, 2761 fish (7.56 fish/day) at the 3G intake, and 1718 fish (4.70 fish/day) at the 5G intake.

BB-3 Impingement at the SRP intakes is strongly seasonal. Approximately 60 percent
BD-5 of the fish impingement at 1G and 3G during 1983-1985 occurred from March through May (63.3 percent at 1G; 58.4 percent at 3G; Figure C-7). Almost 93 percent of impingement at the 5G intake occurred during these months. The largest number of impinged fish were collected in May, when approximately one-third of the annual impingement occurred over the three-year period at 1G and 3G. However, 65 percent of annual impingement at the 5G intake occurred during April. No month other than March, April, and May exhibited greater than ten percent of the annual average impingement at the 1G intake. However, substantial impingement occurred during January (11.1 percent) and December (12.3 percent) at the 3G intake. Impingement was low during the late summer and fall months at all intakes.

At least 62 species of fish, representing 17 families, were impinged at SRP intakes from March 1982 to December 1985 (Tables C-28 and C-29). Twenty species were collected in such abundance that the species collection represented more than one percent of the total collections between September 1982 and September 1985 (Table C-28). Blue-spotted sunfish (23.29 percent) and threadfin shad (11.39 percent) were the most abundant species in impingement samples at all intakes during this three-year period. Among the remaining species only gizzard shad (6.31), redbreast sunfish (5.49 percent), and warmouth (5.30 percent) exceeded five percent of the total collections. Thus, overall impingement losses from the Savannah River were fish identified as forage species with little commercial or recreational value.

However, species specific impingement varied substantially among the three intakes and among years. For the period from September 1982 through August 1983, blue-spotted sunfish dominated impingement collections at the 1G and 5G

Table C-27. Total Annual Impingement at 1G, 3G and 5G Intakes^a

Year		Intake		
		1G	3G	5G
1982	Total fish collected	73	284	84
	Number of days sampled	43	43	43
	Average impingement/day	1.70	6.60	1.95
	Estimated annual impingement	619.7	2410.7	713.0
1983	Total fish collected	1462	1150	1282
	Number of days sampled	100	100	100
	Average impingement/day	14.62	11.50	12.82
	Estimated annual impingement	5336.3	4197.5	4679.3
1984	Total fish collected	655	766	59
	Number of days sampled	101	101	101
	Average impingement/day	6.48	7.58	0.58
	Estimated annual impingement	2367.0	2768.2	213.2
1985 ^b	Total fish collected	430	339	67
	Number of days sampled	94	94	94
	Average impingement/day	4.57	3.61	0.71
	Estimated annual impingement	1669.7	1316.3	260.2
1983-85 ^c average	Total fish collected	849.0	751.7	469.3
	Number of days sampled	98.3	98.3	98.3
	Average impingement/day	8.56	7.56	4.70
	Estimated annual impingement	3124.3	2760.7	1717.6

a. Source: DOE, 1987.

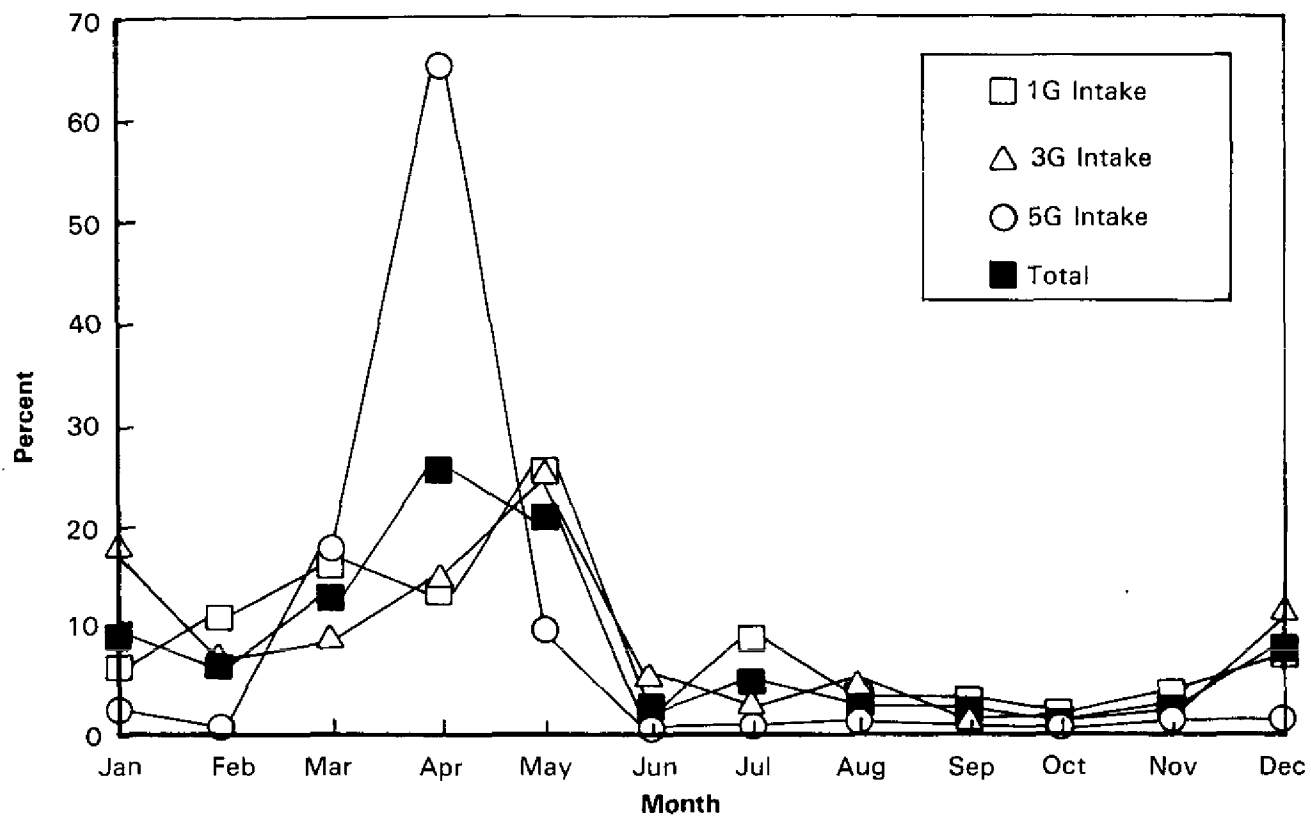
b. Includes unpublished data from October-December 1985.

c. Only 1983-85 data were used for these calculations because sampling was limited in 1982.

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intakes while threadfin shad dominated collections at 3G (Figure C-8a). From September 1983 through August 1984 threadfin shad dominated collections at the 1G intake and blue-spotted sunfish were a relatively minor component of the 1G collections (Figure C-8b). Blue-spotted sunfish dominated collections at the 3G and 5G intakes during this latter period. From September 1984 through September 1985 impingement collections were relatively low at all intakes and gizzard shad were most abundant in 1G intake collections, threadfin shad dominated collections at 3G, and American shad were most abundant at the 5G intake (Figure C-8c). Centrarchids did not dominate the collections at any of the three intakes during this last period.

**Impingement at SRP Intakes
1983-1985**



Source: DOE, 1987

**Figure C-7. Monthly Percentage of Total Annual Impingement at 1G, 3G, and 5G Intakes.
Average Values for 1983-85.**

Table C-28. Number and Percentages of Fish Species Representing Greater Than One Percent of Impingement Collections at the 1G, 3G and 5G Intakes, September 1982-September 1985^a

Species	Number	Percent
Bluespotted sunfish	1465	23.30
Threadfin shad	716	11.39
Gizzard shad	397	6.31
Redbreast sunfish	345	5.49
Warmouth	333	5.30
Flier	313	4.98
Hogchoker	252	4.01
Spotted sunfish	218	3.47
Bluegill	179	2.85
Black crappie	171	2.72
Bowfin	162	2.58
Blueback herring	141	2.24
Spottail shiner	122	1.94
Pirate perch	119	1.89
Dollar sunfish	112	1.78
Pumpkinseed	85	1.35
White catfish	82	1.30
Redfin pickerel	77	1.22
Flat bullhead	70	1.11
Mud sunfish	69	1.10
Total of minor species	<u>860</u>	<u>13.68</u>
Total	6288	100.00

a. Source: DOE, 1987.

The impingement of fish at SRP intakes appears to be strongly selective and relative to the abundance of fish in the intake canals. Quarterly electrofishing of the intake canals revealed that the fish community in the canals is strongly dominated by centrarchids (Figures C-8a, C-8b, and C-8c). During the sampling period September 1982 through September 1985, the electrofishing collections were dominated by a mixture of bluegill, redbreast, and dollar sunfish at all intake areas. Chain pickerel were collected routinely, while yellow perch, suckers, largemouth bass, and spotted sunfish appeared less routinely in collections, but occasionally in substantial numbers. The most notable exception to this pattern is the dominance of flat bullhead, white catfish, and channel catfish in collections near the 5G intake during September 1984 through September 1985. Generally, those species that were dominant in electrofishing collections were not abundant in impingement collections.

BB-3
BD-5

The findings on the relative abundance of fish in the Savannah River near the SRP intakes and in the impingement collections were analyzed relative to the

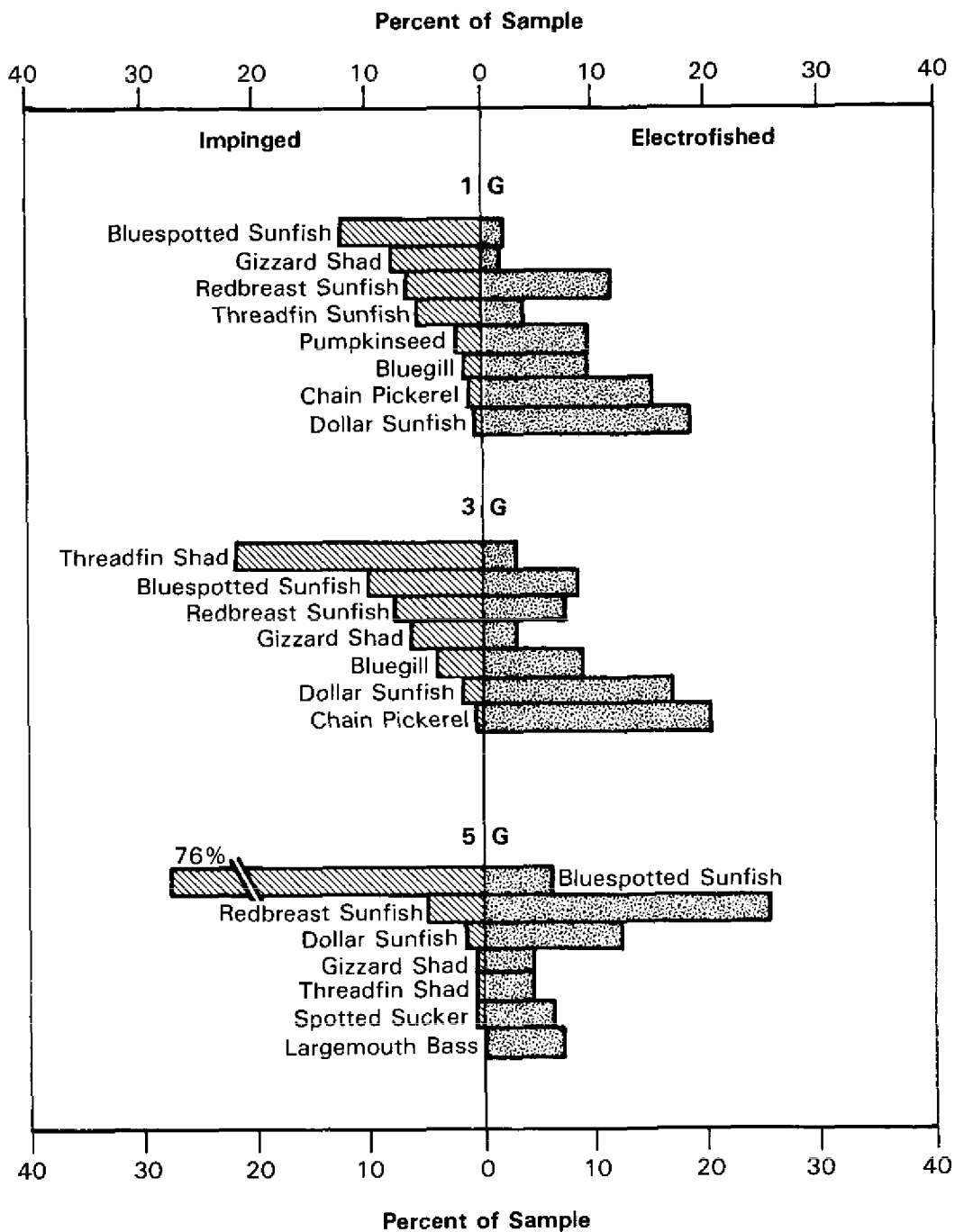
Table C-29. Species of Fish Collected at the 1G, 3G, and 5G Intakes Representing Less Than One Percent of Total Collections, September 1982-September 1985^a

Hickory shad	Speckled madtom
American shad	Margined madtom
Chain pickerel	Redear sunfish
Golden shiner	Blackbanded sunfish
Pugnose minnow	Largemouth bass
Ochoopee shiner	Banded sunfish
Coastal shiner	White crappie
Bannerfin shiner	Green sunfish
Carp	Yellow perch
Whitefin shiner	Blackbanded darter
Eastern silvery minnow	Tessellated darter
Spotted sucker	Swamp darter
Creek chubsucker	Mudminnow
Lake chubsucker	Eastern mudminnow
Chubsucker	Atlantic sturgeon
Silver redhorse	American eel
Channel catfish	Unidentified killifish
Snail bullhead	Mosquitofish
Brown bullhead	Brook silverside
Yellow bullhead	Striped bass
Tadpole madtom	Atlantic needlefish

a. Source: DOE, 1987.

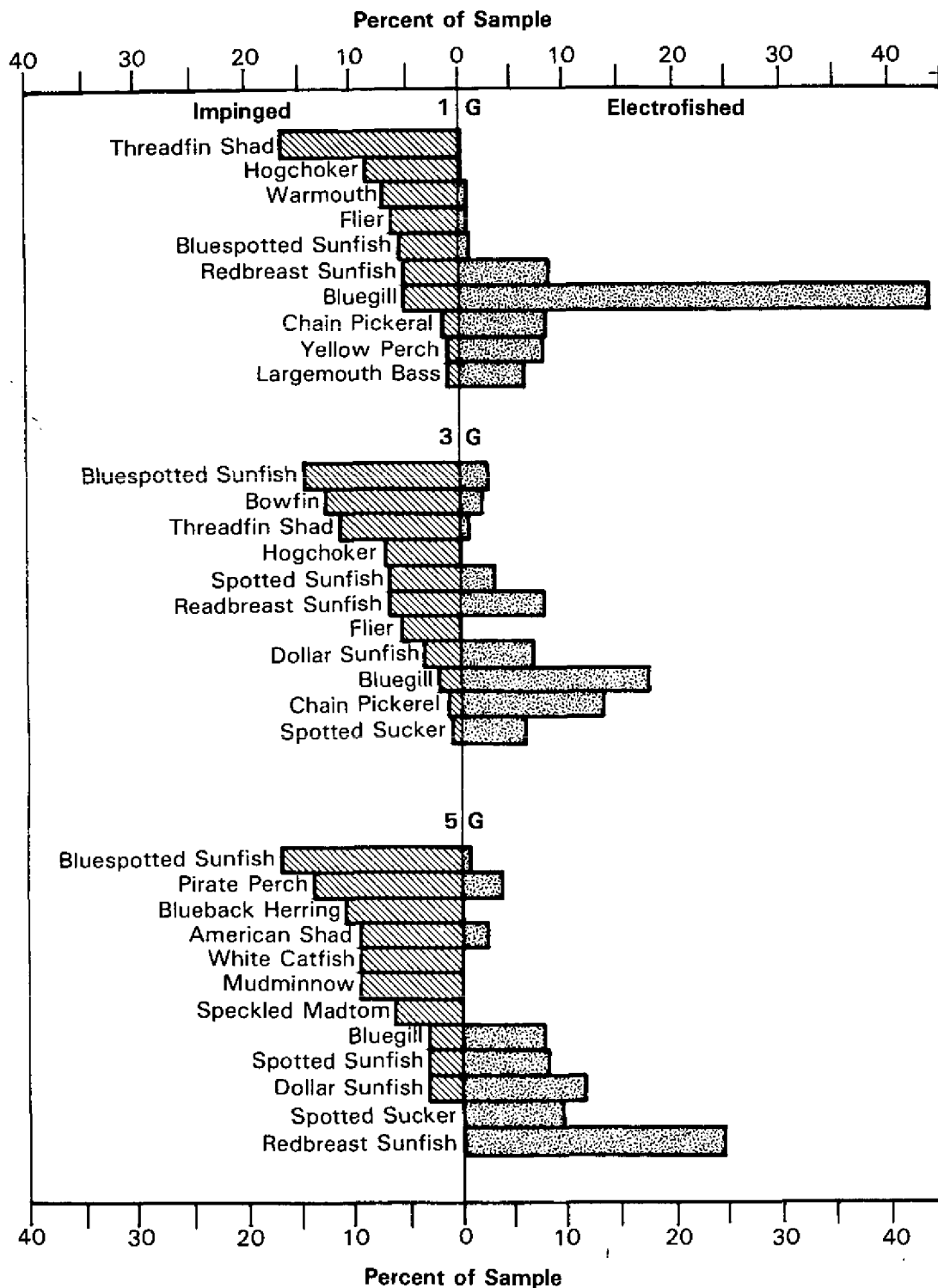
angler catches in freshwater sections of the Savannah River. Fish species caught by anglers in the Savannah River represent an extremely limited set of available species. Electrofishing collections made during 1980-1982 throughout the freshwater sections of the lower Savannah River have indicated that the taxa caught by anglers represented only 33.1 percent of the numerical abundance collected in electrofishing. Similarly, those species that constitute 95.8 percent of the angler catch constitute only 27.8 percent of total impingement at the SRP intakes. The species caught by anglers represent 59.8 percent of the fish caught by electrofishing and 86.9 percent of hoop-net sampling from the Savannah River near the SRP intakes. However, Paller and Osteen (1985) noted that the electrofishing collections near SRP do not accurately reflect the abundance of minnows and other small species. The same caution undoubtedly applies to hoop-net collections because the hoop-nets used for the SRP collections had a maximum mesh size of 37 millimeters.

Bream represent the largest component of the anglers' catch in the Savannah River. Although centrarchids were a substantial component of SRP impingement collections, the species impinged were not predominantly those caught by anglers (Figure C-9). Although redbreast sunfish are abundant in the creel (27.1 percent and in the river near the intakes (26.7 percent), they represented only 5.5 percent of impingement. Bluegill show much higher



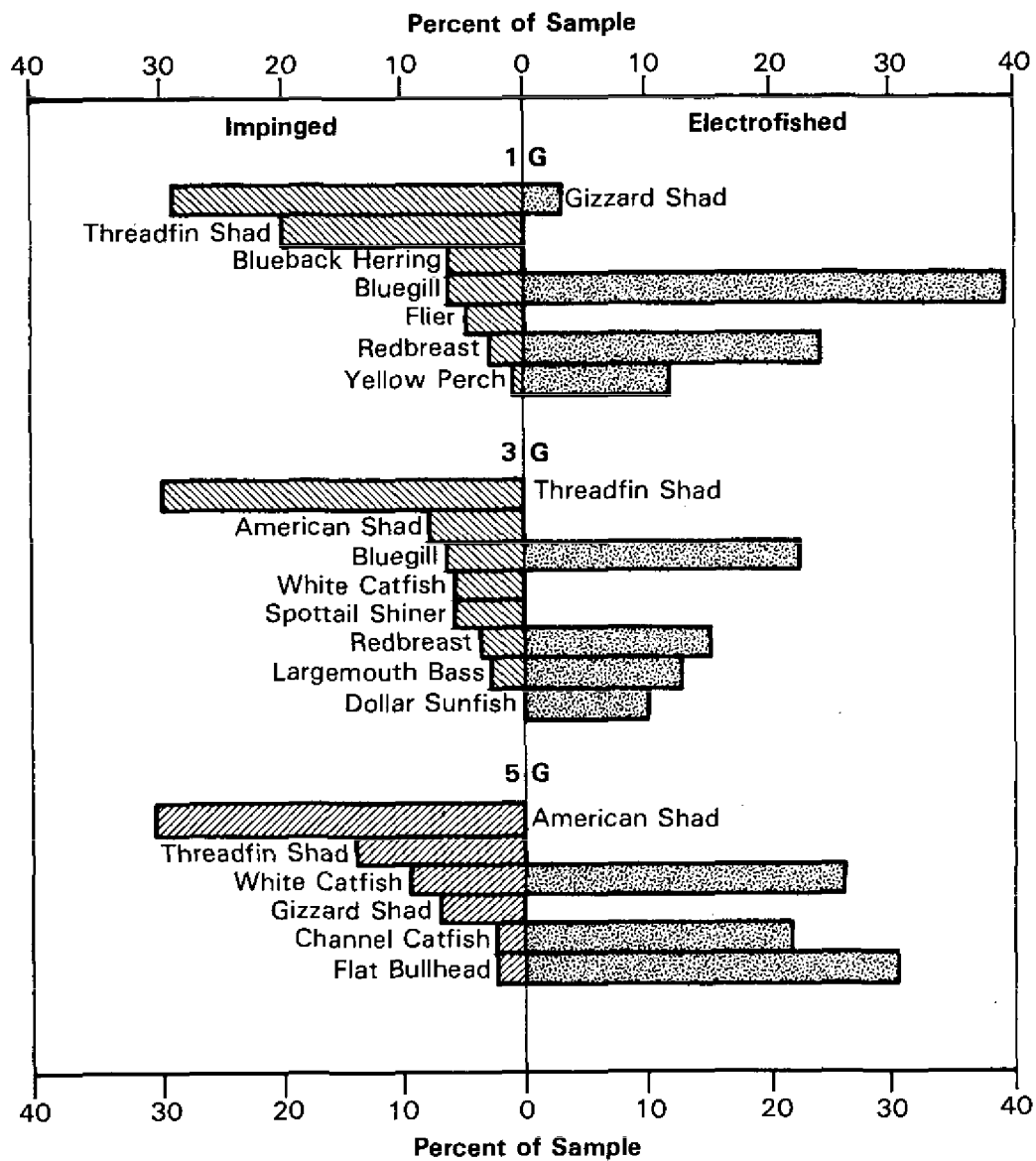
Source: DOE, 1987 from Paller et al. 1984

Figure C-8a. Percent Composition of Selected Fish Species Impinged at the 1G, 3G, and 5G Pumphouses and Collected Near the Pumphouse by Electrofishing. September 1982-August 1983



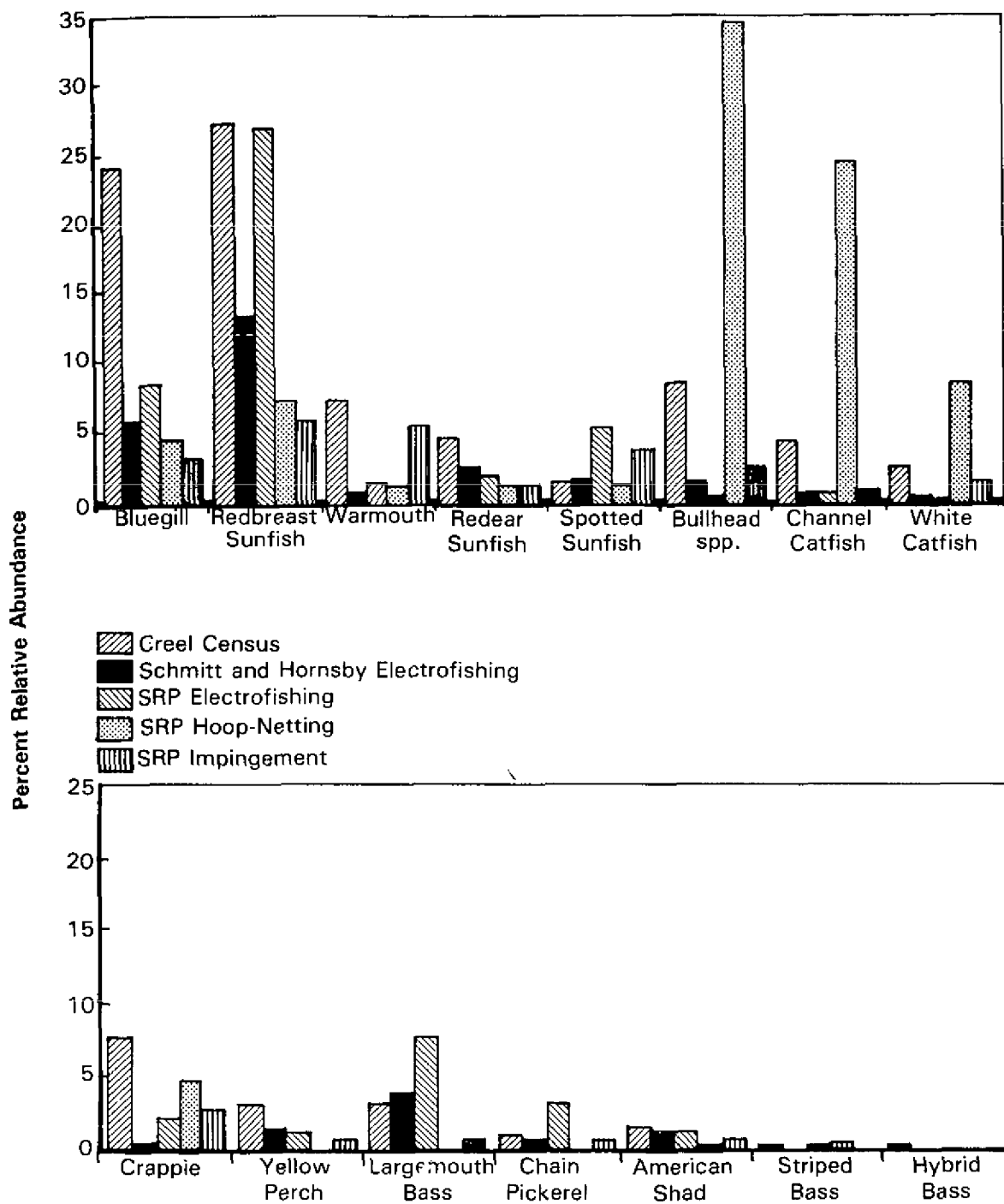
Source: DOE, 1987 from Paller and Osteen, 1985

Figure C-8b. Percent of Composition of Selected Fish Species Impinged at the 1G, 3G, and 5G Pumphouses and Collected Near the Pumphouse by Electrofishing. September 1983-August 1984



Source: DOE, 1987 from Paller and Saul, 1986

Figure C-8c. Percent Composition of Selected Fish Species Impinged at the 1G, 3G, and 5G Pumphouses and Collected in the Vicinity of the Pumphouses by Electrofishing. September 1984-September 1985



Source: DOE, 1987

Figure C-9. Relative Abundance of Fish Taxa in Creel, Electrofishing and Hoop-Net Collections, and SRP Impingement

relative abundance in the anglers' catch than in the river (all methods) and impingement. Among the bream caught by anglers, only the spotted sunfish represents a higher relative abundance in impingement (3.5 percent) than in the creel (1.1 percent), but the species relative abundance in impingement is less than the relative abundance in electrofishing collections (5.2 percent).

Crappie, yellow perch, and largemouth bass all exhibit higher relative abundances in the creek (8.0 percent, 3.0 percent, and 3.2 percent, respectively) than in impingement (2.9 percent, 0.8 percent, and 0.5 percent, respectively, Figure C-9). All three species exhibit higher relative abundance in the river (by at least one collection method) than in impingement. Largemouth bass exhibits higher abundance in the river (by at least one collection method) than in impingement, and exhibits higher relative abundance in the river than in the creel. Chain pickerel is a minor component of the creel (0.9 percent) and has comparable abundance in impingement (0.7 percent).

Relative abundances of all taxa of catfish [bullhead spp. (2.1 percent), channel catfish (0.8 percent), and white catfish (1.3 percent)] taken in impingement samples were lower than relative abundances for those taxa in the creel (8.2 percent, 4.2 percent, and 2.1 percent, respectively, Figure C-9). However, the relative abundances of these taxa in hoop-net collections from the river were substantially higher than for either impingement or angler catches. The disparity between relative abundances of catfish taxa in electrofishing and hoop-net collections suggests that catfish are a substantial component of the Savannah River ichthyofauna, and that electrofishing provides a poor estimate of the abundance of these taxa.

BB-3

American shad, striped bass and hybrid bass were minor components with all of the collection methods (angling, electrofishing, hoop-netting, impingement, Figure C-9). The abundance of the migratory American shad and striped bass in the Savannah River near SRP was undoubtedly underestimated during the quarterly sampling program. Nevertheless, the low frequency of these species in impingement collections (taken in approximately 100 collections throughout the year) is highly encouraging because it indicates that adults and juveniles of these species are minimally influenced by impingement mortality associated with SRP operations.

Status of Savannah River Fish Populations

The primary source documents containing the data used in this section are referenced in DOE (1987).

TE

Relatively little is known about the current status of fishery stocks in the Savannah River and the overall levels of mortality sustained by individual species populations. The creel survey in DOE (1987) represents a significant addition to the knowledge of sports fishing pressure on individual species in freshwater and estuarine areas of the lower Savannah River. Concurrent sampling of the creel census areas using electrofishing and rotenone provided additional information on abundance and species composition of resident species.

BB-3

American shad stocks appear to be healthy and productive in the Savannah River. Reports on commercial catches by Georgia shad fishermen in 1980 indicated that the Savannah River produced the greatest catches (in pounds of

fish and income) in the state, representing 51 percent of Georgia shad landings in that year, while only 13 percent of Georgia's commercial shad fishermen operated in the river during that year. Thus, American shad stocks in the Savannah River may be less heavily exploited and relatively more abundant than stocks in other Georgia rivers. Additionally, researchers have reported on the development of a previously undocumented sport fishery for American shad in the vicinity of the New Savannah Bluff Lock and Dam, and have recommended that the magnitude of this fishery be evaluated.

Less is known about the status of striped bass in the Savannah River. Only recently has spawning upstream of tidally influenced regions of the river been documented (ECS, 1983, Paller et al., 1984, Paller et al., 1985, Paller et al., 1986). Nevertheless, it has been suggested that striped bass spawning occurs primarily in the tidally influenced portions of the river. It is not clear whether the current spawning of striped bass in upstream regions of the river represents a re-establishment of a spawning stock in this area, or is a result of the increased intensity of sampling efforts during 1982-1985 relative to prior sampling programs.

BB-3

Although relatively little is known concerning fish stocks, the quality of fish habitat in the river near the SRP has likely improved. The recent improvement of the sewage treatment facilities in Aiken County, South Carolina, have undoubtedly resulted in improvement of water quality in Horse Creek, which enters the Savannah River at RM 197.4. The continuing upgrading of sewage treatment facilities for the Augusta, Georgia, area will result in improved water quality in Butler Creek (RM 187.2) which enters the river near the New Savannah Bluff Lock and Dam. The river section from the New Savannah Bluff Lock and Dam to downstream of Spirit Creek (RM 182.2) has been identified as an area of degraded water quality.

Overall, there is currently no basis for concluding that fish stocks in the Savannah River are adversely affected by SRP operations. Although direct assessment of recent changes in fish stocks is currently not feasible, the losses of fish resulting from SRP operations are small and localized. Such small losses should not result in a significant risk to the abundance or persistence of fish stocks in the lower Savannah River.

Thermal Effects on Larval Fish

Studies of the thermal tolerance of early life stages of largemouth bass, bluegill, and channel catfish indicated that these species can tolerate higher (several degrees) temperature than the highest observed spawning temperature (Du Pont, 1985). The optimal temperatures for largemouth bass and channel catfish larvae were found to be 24°C and 28°C, respectively. The 24-hour median lethal temperature for largemouth bass larvae was found to range from 32°C to 36°C, while that for bluegill larvae was 36°C to 38°C. The incipient lethal temperature for channel catfish larvae was determined to be 33°C to 36°C. Studies on cold shock conducted on early life stages of largemouth bass and channel catfish indicated that neither species would be likely to suffer mortality if stream temperatures returned to ambient levels during the late spring spawning season.

TE

Fish kills from cold shock can be equally important in environments such as Four Mile Creek and Pen Branch that are thermally constant for long periods of

time during extended reactor operation, and then cool rapidly when reactor operations stop (Du Pont, 1985).

Chlorination/Dechlorination Effects

Experimental studies were conducted to evaluate the potential effects of chlorination and dechlorination of K- and C-Reactor cooling water (Wilde, 1987). Chlorination is expected to be necessary to prevent biofouling of the proposed cooling tower systems for these reactors and dechlorination may be necessary to meet expected NPDES permit limitations on residual chlorine in the receiving streams.

Testing of chlorine demand and dissipation rates in April and May 1986 using K-Reactor cooling water effluent determined that a chlorine dose of approximately 3 mg/l is required to obtain a free residual chlorine (FRC) concentration of 1 mg/l in reactor cooling water (the FRC concentration typically required to prevent biofouling in cooling tower systems). The average total residual chlorine (TRC) concentration resulting from this chlorine dose was 1.7 mg/l.

Reduction of TRC to approximately background levels was usually achieved with a sodium sulfite dose of 1.5 times the calculated stoichiometric concentration. However, 2 times the stoichiometric amount of sodium sulfite produced slightly better dechlorination effectiveness. Therefore, based on the results of this study, with a chlorine dosage (ca. 3 mg/L) providing FRC and TRC concentrations of 1.0 and 1.7 mg/l, respectively, a sodium sulfite dose of approximately 6 mg/l would reduce TRC in the effluent to near background levels.

BB-1
BC-16

Static 48-hour bioassays with bluegill collected from Par Pond showed no toxicity for cooling water containing up to 64 times the stoichiometric concentration of sodium sulfite calculated to remove residual chlorine.

In flow-through 96-hour bioassays with young-of-the-year largemouth bass and bluegill, no mortality occurred with chlorination at peak doses as high as 1.3 mg/L TRC at 20°C. At 30°C, LC 50 values for peak chlorine dosages ranged from 0.8 to 1.1 mg/l TRC. In the flow-through tests no mortality occurred with either species in chlorinated cooling water dechlorinated with 6 mg/l of sodium sulfite.

A sodium sulfite dose of as much as 25 mg/l resulted in no significant reduction in dissolved oxygen or change in pH with a contact time of 150 minutes. The concentration dosages required for substantial dissolved oxygen depletion were found to be more than an order of magnitude greater than the concentration (6 mg/l) proven to effectively dechlorinate SRP cooling water effluent chlorinated to an FRC concentration of 1 mg/l.

C.6 ENDANGERED AND THREATENED SPECIES

The Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.), is intended to prevent the further decline of endangered and threatened species and to bring about the restoration of these species and their habitat. The U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Service

(NMFS) jointly administer this Act. The Act affords protection to some 300 species of native American plants and animals. A species can be listed Federally under either of two categories, "endangered" or "threatened," depending on its status and the degree of the threat. Endangered refers to a species or subspecies that is in danger of extinction throughout all or a significant portion of its range. Threatened means any species or subspecies that is likely to become endangered in the foreseeable future throughout all or a significant portion of its range. In addition, species may also be classified as "threatened due to similarity of appearance." This classification is afforded various species to ensure against excessive taking and to continue necessary protection to similar appearing species which are still classified as threatened. When a species is proposed for either the endangered or the threatened status, areas essential to its survival or conservation are proposed as "critical habitat," when appropriate. Compliance with the Endangered Species Act requires Federal agencies to consult with FWS and/or the NMFS regarding the implementation of a proposed action. If FWS or NMFS indicate that an endangered or threatened species (or one proposed as such) or critical habitat could be present in the area of the proposed action, a biological assessment must be prepared. This assessment is used as a basis for evaluating the effects on Federally protected species through the formal consultation process.

The State of South Carolina has a Nongame and Endangered Species Conservation Act (Section 50-15, 1976, S.C. Code of Laws). Rules established to implement the act protect Federally protected endangered and threatened wildlife that occur in South Carolina (R.123-150), sea turtles (R.123-150.1) and predatory birds of the orders Falconiformes and Strigiformes (R.123-160). The State does not afford protection to flora other than Federally protected species (DOE, 1982). Additions to the State protection listings can be made by the South Carolina Wildlife and Marine Resources Commission.

Table C-30 lists species of flora and fauna that have been documented at the Savannah River Plant (Dukes, 1984) and have been listed by the Federal Government (50 CFR 17.11 and 17.12, "Endangered and Threatened Wildlife and Plants") or State of South Carolina as endangered, threatened, or of special concern. The Savannah River Plant contains no areas that have been designated as critical habitat for any species.

TC Formal consultations were held between DOE and the U.S. Fish and Wildlife Service to comply with the Endangered Species Act of 1973. Based on these consultations, the FWS issued a biological opinion that the preferred alternative cooling systems should have no effect on endangered and threatened species (Parker, 1986; Henry, 1986).

C.6.1 AMERICAN ALLIGATORS

TE Sections 6.1 through 6.5 address the threatened and endangered species that occur on the Savannah River Plant. Much of the information presented in these sections is summarized from the Comprehensive Cooling Water Study (Du Pont, 1985). Additional information concerning other species listed in Table C-30 is in DOE, 1984.

Formerly high alligator population levels in the United States were greatly reduced by habitat alteration, indiscriminate killing, and legal, as well as

Table C-30. Species on the Federal List of Endangered Species or the South Carolina List of "Endangered," "Threatened," or "Of Special Concern" Species That Might Occur on the Savannah River Plant^a

Species	Status				Observations on or near SRP
	Federal ^b		State		
	Threatened	Endangered	Threatened	Special concern	
<u>Mammals</u>					
<u>Ursus a. americana</u> (Black bear)			X		No resident population on SRP, observation infrequent in past
<u>Lynx rufus</u> (Bobcat)				X	Common on SRP
<u>Lutra canadensis</u> (River otter)				X	Observed along ambient streams of SRP
<u>Spilogale p. putorius</u> (Eastern spotted skunk)				X	Common on SRP
<u>Condylura cristata parva</u> (Star-nosed mole)				X	Collected infrequently near Risher Pond, Ellenton Bay, Rainbow Bay, and Steel Creek floodplain
<u>Birds</u>					
<u>Picoides borealis</u> (Red-cockaded woodpecker)		X			A few scattered colonies in pine stands of SRP; see text for more details
<u>Haliaeetus l. leucocephalus</u> (Bald eagle)		X			Thirty-six birds have been observed on the SRP, most of which have occurred on Par Pond and L-Lake. A single active nest containing two juveniles was located below Par Pond dam in the Lower Three Runs Creek drainage area in 1986.
<u>Mycteria americana</u> (Wood Stork)		X	X		Individuals have been observed foraging in the Savannah River swamp; see text for more details

TC

Table C-30. Species on the Federal List of Endangered Species or the South Carolina List of "Endangered," "Threatened," or "Of Special Concern" Species That Might Occur on the Savannah River Plant^a
(continued)

Species	Status				Observations on or near SRP
	Federal ^b		State		
	Threatened	Endangered	Threatened	Special concern	
<u>Birds (continued)</u>					
<u>Pandion haliaetus</u> (American osprey)			X		A few individuals have been observed as migrants over SRP
<u>Accipiter cooperii</u> (Cooper's hawk)			X		A few individuals have been observed near Sun Bay and Rainbow Bay
<u>Bubo virginianus</u> (Great horned owl)				X	A few individuals have been observed near Rainbow Bay
<u>Melanerpes erythrocephalus</u> (Red-headed woodpecker)				X	Common on SRP
<u>Picoides villosus</u> (Hairy woodpecker)				X	Common on SRP
<u>Lanius ludovicianus</u> (Loggerhead shrike)				X	Infrequently observed on SRP
<u>Aythya valisineria</u> (Canvasback)				X	
<u>Ictinia mississippiensis</u> (Mississippi kite)				X	
<u>Reptiles</u>					
<u>Alligator mississippiensis</u> (American alligator)	X ^c		X		Common on Par Pond, Beaver Dam Creek, and in the SRP Savannah River Swamp; see text for more details
<u>Clemmys guttata</u> (Spotted turtle)				X	Uncommon

TC

TC

Table C-30. Species on the Federal List of Endangered Species or the South Carolina List of "Endangered," "Threatened," or "Of Special Concern" Species That Might Occur on the Savannah River Plant^a
(continued)

Species	Status				Observations on or near SRP
	Federal ^b		State		
	Threatened	Endangered	Threatened	Special concern	
<u>Reptiles (continued)</u>					
<u>Natrix cyclopion</u> (Green water snake)				X	Collected commonly from Ellenton Bay
<u>Seminatrix pygaea</u> (Carolina swamp snake)				X	Uncommon; collected from Ellenton Bay
<u>Virginia valeriae</u> (Smooth earth snake)				X	Collected from deciduous forests mixed with older pines; found near Pond C or Par Pond, Lost Lake, and Rainbow Bay
<u>Pituophis m. melanoleucus</u> (Pine snake)				X	Uncommon
<u>Micrurus f. fulvius</u> (Eastern coral snake)				X	Uncommon
<u>Ophisaurus attenuatus longicaudus</u> (Eastern slender glass lizard)				X	Uncommon; has been collected near Risher Pond, Rainbow Bay, Sun Bay, and Steel Creek floodplain
<u>Amphibians</u>					
<u>Ambystoma t. tigrinum</u> (Eastern tiger salamander)				X	Found throughout SRP
<u>Pseudacris triseriata feriarum</u> (Upland chorus frog)				X	Locally common
<u>Hyla avivoca ogechiensis</u> (Bird-voiced treefrog)				X	Locally common in the Savannah River swamp

TC

Table C-30. Species on the Federal List of Endangered Species or the South Carolina List of "Endangered," "Threatened," or "Of Special Concern" Species That Might Occur on the Savannah River Plant^a
(continued)

Species	Status				Observations on or near SRP
	Federal ^b		State		
	Threatened	Endangered	Threatened	Special concern	
<u>Amphibians (continued)</u>					
<u>Rana grylio</u> (Pig frog)				X	Observed near Steel Creek Bay and Steel Creek delta
<u>Rana palustris</u> (Pickerel frog)				X	Rare; a few have been captured from Risher Pond
<u>Fish</u>					
<u>Acipenser brevirostrum</u> (Shortnose sturgeon)		X			Rare; a few larvae (5) have been collected in the Savannah River near the SRP pumphouses and two larvae were collected in the intake canals; see Section C.5.2.2 for more details
<u>Acipenser oxyrinchus</u> (Atlantic sturgeon)			X		Rare; a few larvae (17) have been collected in the Savannah River near the SRP pumphouses; see Section C.5.2.2 for more details
<u>Alosa aestivalis</u> (Blueback herring)				X	Common in the Savannah River; present in Par Pond
<u>Alosa mediocris</u> (Hickory shad)				X	Collected downstream of SRP in the Savannah River
<u>Invertebrates</u>					
<u>Elliptio fraterna</u> (Brother spike mussel)		X			Collected from Savannah River below Lower Three Runs Creek
<u>Elliptio lanceolata</u> (Yellow lance mussel)				X	Collected from ambient streams of SRP and the Savannah River
<u>Alasmidonta triangulata</u> (Triangle floater mussel)			X		Collected from Savannah River below SRP

TC

TC

Table C-30. Species on the Federal List of Endangered Species or the South Carolina List of "Endangered," "Threatened," or "Of Special Concern" Species That Might Occur on the Savannah River Plant^a
(continued)

Species	Status				Observations on or near SRP
	Federal ^b		State		
	Threatened	Endangered	Threatened	Special concern	
<u>Invertebrates (continued)</u>					
<u>Carunculina pulla</u> (Savannah shore mussel)			X		Collected from Savannah River near Lower Three Runs Creek
<u>Anodonta couperiana</u> (Barrel floater mussel)				X	Collected from Savannah River and Lower Three Runs Creek at Donora Station
<u>Strophitus undulatus</u> (Strange floater mussel)				X	Collected from Savannah River downstream of Steel Creek
<u>Lampsilis cariosa</u> (Yellow mucket mussel)				X	Collected from Savannah River and Lower Three Runs Creek
<u>Lampsilis radiata splendida</u> (Red mucket mussel)				X	Collected from Savannah River, Lower Three Runs Creek, and Tinker Creek
<u>Procambarus hirsutus</u> (Crayfish)				X	Collected from ambient streams of SRP
<u>Tortopus incertus</u> (Mayfly)				X	Collected from clay banks in the Savannah River near Upper Three Runs Creek and Steel Creek mouth
<u>Plants</u>					
<u>Echinacea laevigata</u> (Smooth coneflower)		X			Along Burma Road
<u>Nestronia umbrellula</u> (North American sandlewood)				X	Dry wood bluffs along Upper Three Runs Creek
<u>Habenaria lacera</u> (Green fringed-orchid)				X	Rainbow Bay, Sun Bay, and Mill Creek Reserve Site areas

TC

Table C-30. Species on the Federal List of Endangered Species or the South Carolina List of "Endangered," "Threatened," or "Of Special Concern" Species That Might Occur on the Savannah River Plant^a
(continued)

Species	Status				Observations on or near SRP
	Federal ^b		State		
	Threatened	Endangered	Threatened	Special concern	
<u>Plants (continued)</u>					
<u>Ludwigia spathulata</u> (Spathulate seedbox)			X		Sun Bay and transplanted to Rainbow Bay area
<u>Enchinodorus parvulus</u> (Little burhead)			X		Lost Lake and Sun Bay
<u>Rhexia aristosa</u> (Ann-petaled meadow-beauty)			X		Craig Pond
<u>Ipomopsis rubra</u> (Standing cypress)			X		On roadbank of Highway 125 just east of SRP boundary in Barnwell County, SC
<u>Coreopsis rosea</u> (Pine tickseed)			X		Karen's Pond and Flamingo Bay

a. Source: Dukes, 1984.

b. Source: 50 CFR 17.11 and 17.12.

c. Threatened due to similarity of appearance.

illegal commercial harvest (Du Pont, 1985). By the 1950s, alligator populations were at an all-time low. Since that time, State and Federal law enforcement and management, as well as public education, have allowed the alligator to recover throughout much of its range. On June 4, 1987, FWS reclassified the American alligator from endangered to threatened due to similarity of appearance because the species is no longer biologically endangered or threatened throughout its range (FR 52 No. 107: 21059-21064). The threatened due to similarity of appearance status was retained to ensure against excessive taking and to continue necessary protection to the American crocodile, a morphologically similar species.

Alligators will feed on most aquatic and semiaquatic vertebrates and some terrestrial animals. Limited data suggest that fish make up the bulk of the alligator diet on the Savannah River Plant (Du Pont, 1985). American alligators have relatively broad temperature tolerances; the critical thermal maximum is estimated to be 38°C and animals have survived exposure to temperatures as low as 2°C to 4°C (Colbert, Cowles, and Bogert, 1946; Hagan, Smithson, and Doerr, 1983).

The American alligator occupies most major aquatic habitats at the Plant where water temperatures are suitable and food supplies are adequate (Du Pont, 1985). Large alligator populations occupy Par Pond and Beaver Dam Creek, areas that receive cooling water but have only moderately elevated temperatures. The Par Pond population has been studied most intensively; historically it has shown population parameters that indicated reduced reproduction in relation to more southerly populations. However, recent surveys indicated more extensive reproduction and a normalization of the age and sex structures (Du Pont, 1985). Recent surveys also indicate that Beaver Dam Creek might represent the most dense population of American alligators (Du Pont, 1985). At least 40 individuals were documented in less than 6 kilometers of the stream; clear evidence (i.e., two "pods" of hatchlings located 100 meters apart) indicated recent and successful reproduction (Du Pont, 1985).

Reproducing populations of alligators are known to occur in both post-thermal SRP stream systems, Steel Creek and Lower Three Runs Creek (Du Pont, 1985). A few alligators have been observed to move upstream in the reactor effluent streams when the reactors are not operating. Experimental studies confirm that alligators avoid lethal water temperatures associated with reactor start-up, even in winter when the animals' metabolic rates are low (Du Pont, 1985).

SRP operations have impacted the alligator population in many different ways. The creation of manmade reservoirs has dramatically increased the amount of aquatic habitat available to alligators. Therefore, it has increased the carrying capacity of the Plant for this species (Du Pont, 1985).

The thermal alteration of aquatic habitats has also impacted the resident alligator population (Du Pont, 1985). Temperature elevations greater than 38°C result in the loss of this habitat to alligators. Alligators respond to moderate thermal increases by moving to other locations. Observations suggest that alligators might utilize vertical and horizontal temperature profiles established by thermal loading to maintain their body temperatures at a preferred level; definitive data have not been collected (Murphy, 1981). Alligators around areas of thermal loading might also profit from extended

breeding seasons or increased productivity by prey species. A serious negative influence of moderate levels of thermal loading appears to result from the induction of a premature reproductive season combined with differential use of thermal areas by adult male and female alligators (Murphy, 1981).

The current information available on the alligators of the Savannah River Plant suggests the following predicted trend: low density populations distant from thermally altered areas will continue at a low density with the exception of localized increases. The alligators inhabiting Par Pond should continue a trend toward a more normal size distribution and sex ratio as the reservoir matures and the older adults are replaced by the young (Du Pont, 1985).

C.6.2 WOOD STORKS

TC During the last 50 years the wood stork population declined from an estimated 20,000 breeding pairs in the early 1930s to approximately 4800 pairs in 1980 and 3650 pairs in 1983 (Ogden and Nesbitt, 1979; Ogden and Patty, 1981; DOI, 1983). FWS has listed the wood stork as an endangered species (DOI, 1984; 50 CFR 17.11 and 17.12).

The most northern and inland wood stork colony is located at Big Dukes Pond, a cypress swamp 12.6 kilometers northwest of Millen, Jenkins County, Georgia (Du Pont, 1985). This colony, referred to as the Birdsville colony, is the source of the birds foraging at SRP. The Plant is 45 kilometers from the Birdsville colony, a distance within the 60- to 70-kilometer radius that wood storks can travel during daily feeding flights (Du Pont, 1985).

The wood stork method of feeding is highly specialized. Wood storks wade in shallow pools, 15 to 30 centimeters deep, with their bills extended slightly forward and submerged as far as the external nares and opened about 8 centimeters at the tips. When a stork touches fish or other prey with its bill, the bird snaps the bill shut, capturing the prey. This method has been termed tactolocation. This feeding technique allows wood storks to forage in muddy or turbid water where birds that hunt visually cannot feed. To feed efficiently, storks forage in ponds where prey are concentrated. It is important that the birds feed in areas where prey are densely concentrated during the breeding season because food requirements are greatest when adults are caring for chicks (Kahl, 1964; Du Pont, 1985).

Wood storks are colonial nesters. They build large nests in trees, usually over standing water. Nest heights range from a few meters above water in mangrove swamps to the tops of the tallest cypress trees (Taxodium sp.) (Ogden and Nesbitt, 1979). Storks use cypress trees for nesting habitat most often; however, in southern Florida they use red mangrove, Rhizophora mangle (Kahl, 1964).

Wood storks breed during the dry season when evaporation in shallow ponds concentrates the prey (Du Pont, 1985). Breeding lasts about 120 days, including time for courtship and nest-building. Two to five white eggs are incubated for 28 to 30 days. During the first 30 days after hatching, the young are attended by one parent while the other parent forages. During this period the chicks gain the ability to thermoregulate and grow to a size at which they are no longer vulnerable to their major predators, crows and vultures. As the food demand of the chicks exceeds the level that one parent can

provide, the young are left alone at the nest while both parents forage. The young leave the rookery after about 65 days (Kahl, 1964).

Kahl (1964) estimated that during the breeding season the minimum fish biomass needed by a nesting pair of storks and an average of 2.25 fledged young was 201 kilograms. Feeding habitat, including cypress swamps and domes, scrub cypress, freshwater marshes, and mixed hardwood swamp, must be available within 60 to 70 kilometers of the stork colony. These habitats must also be productive enough to maintain fish populations at levels sufficient to allow an annual take by the colony equal to about 201 kilograms times the number of nesting pairs (Meyers, 1984).

Wood stork feeding sites for the Birdsville colony were studied during the second half of the nesting season in 1983 and for most of the 1984 and 1985 nesting season (Meyers, 1984; Coulter, 1986a,b). Feeding sites were located by following storks from the nesting colony and by surveying the SRP Savannah River swamp and other habitats near the colony. The following information was gathered from this research:

- Wood storks at Birdsville produced an average of 2.2 fledglings per active nest during 1983. About the same number of young were observed in 1984 (2.4 fledglings) and 1985 (2.5 fledglings). When the loss of entire nests is considered, the mean number of young per nest declined from 2.04 in 1984 to 0.33 in 1985.
- Wood storks forage up to 80 kilometers from the colony, but a majority (91 percent) of feeding flights during 1983 were less than 50 kilometers. During 1984, more than 80 percent of the foraging sites were within 20 kilometers and 55 percent were within 10 kilometers of the colony. During 1985, most sites (89 percent) were within 20 kilometers of the colony, and 46 percent were within 10 kilometers of the rookery.
- Of the 50 feeding sites located during 1983, 18 percent were located in SRP swamps (3 sites at the Steel Creek delta, 5 sites at Beaver Dam Creek, and 1 site near the Pen Branch delta) in 1983. Similar areas at SRP were used in 1984, along with additional foraging sites in the swamp between Pen Branch and Four Mile Creek. Two wood storks were observed feeding in Kathwood Lake on August 5, 1984; no other sightings were recorded during the surveys. In 1985, 58 percent of the feeding sites were in swamps and 23 percent were in Carolina bays and ponds.
- Before fledging (when young birds leave the nest) in 1984, 33 percent of the feeding sites were located at SRP. However, of the total number of adult storks observed feeding at that time, 64 percent were at SRP sites and 36 percent were not. During 1985, no wood storks were observed feeding at SRP prior to fledging.
- After fledging, juvenile wood storks did not feed at SRP sites in 1983.
- In 1983, storks fed in shallow pools with an average of 6.2 acres and depths between 10 and 32 centimeters. In 1984 and 1985, the median water depth was 22 and 21 centimeters, respectively. Habitat types for 1983-1985 included black gum swamp, cypress swamp, shrub swamp, open marsh, manmade ponds, and Carolina bays used as feeding sites.

BB-3

BB-3

- Habitat use varied markedly from 1983 to 1985. The Steel Creek delta was heavily used in 1983 and 1984, but was infrequently used in 1985. Beaver Dam Creek was important to wood storks in 1983 and 1984, but none were observed there in 1985. The greatest use in 1985 was recorded on the Four Mile Creek delta and in the area between this delta and the Pen Branch delta.
- Direct and indirect effects from thermal effluent discharge from SRP facilities probably limit the potential use of the Savannah River swamp by foraging adult wood storks.

TE

- If the Florida colonies continue to decline, the Birdsville colony will become relatively more important to the wood stork.

C.6.3 SHORTRNOSE STURGEON

TC

The shortnose sturgeon is listed by the National Marine Fisheries Service (NMFS) as an endangered species in the United States (Du Pont, 1985; 50 CFR 17.11 and 17.12). This species is found only on the east coast of North America in tidal rivers and estuaries. Until recently, the presence of shortnose sturgeon had not been documented in the middle reaches of the Savannah River. However, from 1982 to 1985, shortnose sturgeon larvae were collected near the Savannah River Plant as part of the SRP aquatic ecology program (see Section C.5.2.2; DOE, 1987). Because the shortnose sturgeon is anadromous, protection of this species is under jurisdiction of the NMFS. Critical habitat for this species has not been designated by the NMFS (Du Pont, 1985).

TC

Breeding populations of shortnose sturgeon are normally associated with estuary-river complexes that have a strong flow of fresh water. The shortnose sturgeon's endangered species status has stimulated recent investigations that have shown it to be more abundant in some drainage systems than had been previously known (Brundage and Meadows, 1982).

TE

Shortnose sturgeon have been found in rivers, estuaries, and the ocean with their greatest abundance occurring in the estuary of their respective rivers (Dadswell et al., 1982). The few fish that have been captured at sea were found within a few miles of the mouth of an estuarine system. The species is primarily anadromous, but access to the sea is apparently not a requirement for reproductive success. Landlocked populations have been reported in the Holyoke Pool section of the Connecticut River (Taubert, 1980a,b) and the Lake Marion-Moultrie system in South Carolina (Marchette and Smiley, 1982).

Spawning of shortnose sturgeon occurs between February and May, depending on the latitude. The major factor governing spawning appears to be temperature, although other factors include the occurrence of freshets and substrate character (Dadswell et al., 1982). Several investigators have reported shortnose sturgeon spawning to occur between 9°C and 19°C (Heidt and Gilbert, 1978; Dadswell, 1979; Taubert, 1980a; Buckley and Kynard, 1981). Specific spawning grounds for populations in southeastern rivers have not been described. The shortnose sturgeon exhibits a migration pattern between spawning grounds, feeding grounds, and overwintering areas.

Although a segment of the Savannah River shortnose sturgeon population spawns upstream of SRP cooling water intake canals, entrainment of eggs is unlikely

(Du Pont, 1985). Sturgeon eggs are demersal and are usually deposited on rubble and gravel substrate (Buckley, 1982; Taubert, 1980b). Whether this substrate is utilized or available to the Savannah River population is not known. However, the negative buoyancy and strongly adhesive, gelatinous nature of the eggs preclude significant downstream transport or dispersion of eggs through the water column (Pottle and Dadswell, 1979).

Collections made near SRP indicate that some shortnose sturgeon larvae might be entrained (see Section C.5.2.2). However, it is not possible to accurately estimate entrainment losses due to the low number of specimens collected. Given the small number of shortnose sturgeon larvae collected and the relatively extensive ichthyoplankton sampling effort in the vicinity of the SRP site, the number of larvae entrained probably is small and their loss does not represent an adverse effect on the Savannah River shortnose sturgeon population (Du Pont, 1985).

TC

In January 1983, one 147-millimeter juvenile Atlantic sturgeon was impinged on the intake screens (Du Pont, 1985). Thus, shortnose sturgeon might be impinged. However, there is no evidence that Atlantic or shortnose sturgeon commonly inhabit the intake canals. Shortnose sturgeon, unless injured, should be able to avoid the intake screens because their swim speed exceeds the pumphouse intake velocity (Du Pont, 1985).

Potential direct thermal effects on the shortnose sturgeon are limited to existing and any future thermal plumes in the Savannah River. Thermal plumes should not affect adults because they can avoid these areas; at present, a large zone of passage exists in the Savannah River for all migratory species (Du Pont, 1985). Eggs are not planktonic and should not drift through the plumes; however, newly hatched larvae could be swept into the plume under conditions of high water flow or drift downstream as part of a normal dispersion process. Although there are no temperature tolerance data on larval shortnose sturgeon, larvae drifting through the plume near the mouth of Four Mile Creek might not survive. This potential effect is expected to be limited because only adults spawning immediately above the thermal plume and larvae drifting through the hottest part of the thermal plume would be affected (Du Pont, 1985).

The NMFS had previously concurred in DOE's determination that the population of shortnose sturgeon in the Savannah River would not be adversely affected by SRP operations (Oravetz, 1983).

C.6.4 RED-COCKADED WOODPECKER

The red-cockaded woodpecker was once a common bird in the mature pine forests of the Southeast. Today its range and population have been reduced through loss of habitat. It is unique among North American woodpeckers in its selection of mature, living pines for cavity excavation (Jackson, 1978). The disappearance of mature pine forests (Whalenberg, 1946, 1960; Lennartz et al., 1983) has resulted in fragmentation of the required habitat. As a result, many red-cockaded woodpecker populations exist in isolated mature pine reserves (Jackson, 1977).

The red-cockaded woodpecker has a complex cooperative breeding system (Lennartz and Harlow, 1979). These birds live in groups called clans, are

nonmigratory, and maintain large year-round territories (Ligon, 1970). The clan can consist of from two to nine birds, but there is never more than one breeding pair. The other adults are usually males called helpers. Some clans have no helpers, but others might have as many as three. The helpers assist in incubating eggs, making new cavities, feeding the young, and defending the clan's territory. A breeding male can live for several years. When he dies, one of the helpers usually inherits the status of breeding male (Lennartz and Harlow, 1979).

TE | A clan nests and roosts in a group of cavity trees called a colony. Cavities are made in live pine trees. Each clan member tries to have a cavity for roosting. Birds without cavities in live trees often roost in forks between limbs or in cavities of dead trees. A cavity is seldom excavated in one year, and most take several years of work (Jackson, Lennartz, and Hooper, 1979).

The red-cockaded woodpecker nests between late April and July. Only the breeding male courts and mates with the female. The female usually lays two to four eggs in the breeding male's roost cavity. The breeding male stays with the eggs at night and the clan members take turns incubating during the day. The eggs hatch in 10 to 12 days. Young birds leave the nest in about 25 days (Ligon, 1970). The clan spends a great deal of time looking for food. Most of the foraging is concentrated on the trunks of live pine trees. The birds will scale the bark and dig into dead limbs for spiders, ants, cockroaches, centipedes, and the eggs and larvae of various insects.

The clan defends year-round a territory surrounding the colony. Territories range from less than 100 acres to more than 250 acres. The total area used by the clan can be as large as 1000 acres.

The Savannah River Forest Station's wildlife management program has concentrated on red-cockaded woodpecker habitat improvement since 1979. In July 1980, an intensive program was started to reduce encroaching hardwood understory in several colonies. The objective was to provide the open, park-like mature pine stands that are required. This type of habitat is scarce at SRP. About one-third of the forest area has been planted since 1951 and will require 30 or more years to provide suitable habitat. Much of the remaining area is either scrub oak or bottomland hardwoods.

TC | The Forest Service is in the process of evaluating inventoried colonies of red-cockaded woodpeckers and their habitats and determining which habitats should be improved. No active colonies are located near the areas of proposed alternative cooling water system construction. In 1987, the Plant had three active breeding colonies, and the Southeastern Forest Experiment Station successfully cross-fostered two chicks from the Francis Marion National Forest to stabilize and increase the genetic diversity of the colonies.

C.6.5 BALD EAGLE

TC | The federally endangered bald eagle is a fairly common permanent breeding resident in South Carolina and is most abundant in the coastal region (Sprunt and Chamberlain, 1970). The presence of this species on Par Pond was first recorded in May 1959 (Norris 1963), and has been frequently sighted since 1978 (Mayer et al., 1986). From September 1984 through August 1985, Mayer et al. (1986) reported 36 bald eagles, 92 percent of which were observed on the Par

Pond reservoir system; no active nests, however, were found. From September 1985 to January 1986, a total of 22 birds was observed, some of which were seen in the vicinity of the newly constructed L-Lake reservoir system.	TC
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Bald eagles migrate from southeastern to northern states and Canada in mid-summer; they return south in the fall and early winter to nest and rear their young (Sprunt and Chamberlain, 1970).	TC
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The first sighting of an active bald eagle nest occurred on June 5, 1986, below Par Pond dam in the Lower Three Runs Creek drainage area, and two eaglets fledged from the nest in 1987. Because this nest is outside the preferred alternative cooling impact zones and because of the implementation of management practices in accordance with the guidelines of the 1984 bald eagle recovery plan, the FWS issued a finding of no effect to this species in 1986 (Henry, 1986).	TC
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C.7 COMMERCIALLY AND RECREATIONALLY VALUABLE BIOTA

Commercially valuable plant biota on the Savannah River Plant include approximately 175,000 acres of timber that are managed by the Forest Service. The commercial value of SRP timber that was managed and sold by the Forest Service in 1982 was \$1.7 million; this included pine and hardwood sawtimber, pine pulpwood, and cordwood hardwoods. Approximately 71 percent of the timber sales consisted of pine pulpwood. The longterm trend in planting activities has been an increase in the number of loblolly pine and a decrease in slash pine. The latter is more susceptible to injury from ice glazing and has not been planted since 1970. More than 1,530,000 loblolly pine seedlings and 160,000 longleaf pine seedlings were planted in 1980 (USDA, 1983).	TE
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Public hunts of deer and feral hogs, managed by the Forest Service, began in 1965. These hunts minimize deer-car accidents and maintain habitat quality. Since 1981, Du Pont personnel have planned and managed these hunts.	TE
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The annual number of hunter-days increased from 700 in 1966 to 6325 in 1980; paralleling this trend was an increase from 198 deer harvested in 1966 to 961 in 1980. The harvest of feral hogs ranged from 10 in 1972 to 32 in 1980. Additionally, there has been a relatively consistent decline in the number of deer-car accidents. In the late 1960s and early 1970s, there were more than 50 deer-car accidents; only 11 incidents were reported in 1980.	TE
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Other game species that have commercial and recreational value but have protection from hunting include the bobcat, fox, mink, muskrat, opossum, otter, rabbit, raccoon, skunk, squirrel, migratory waterfowl, bobwhite quail, mourning dove, wild turkey, Wilson's snipe, and woodcock.	TE
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The Savannah River supports both commercial and sports fisheries. Table C-31 lists the species and catches of fish taken commercially from the river from 1970 to 1979. Many of these fisheries are confined to the marine and brackish waters of the coastal regions of South Carolina and Georgia.

The only commercial fishes of significance near SRP are the American shad, the channel catfish, and the Atlantic sturgeon. These species, except for the

Table C-31. Commercial Landing Data for Fish Taken from Savannah River, 1970-1979^a

Species	Combined catches in Georgia and South Carolina (kg)									
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Carp	0	250	252	1,503	590	998	136	453	136	363
Catfish	544	157	222	518	726	1,814	1,043	1,043	363	1,043
Black drum	0	0	0	0	0	227	272	0	0	0
Red drum	0	0	0	0	45	0	181	499	136	0
Hickory shad	318	384	291	725	91	227	91	136	181	91
Spotted sea trout	0	0	0	324	227	2,500	1,800	181	181	0
American shad	43,591	25,568	25,439	33,912	26,263	20,412	8,618	20,820	54,432	57,607
Sturgeon	726	23	1,967	551	136	45	363	862	454	227
Suckers	0	0	0	0	0	0	91	0	0	0
Common eels	0	0	0	0	0	91	0	45	0	45
Mullet	0	0	0	0	0	227	0	91	0	0
Striped bass	816	735	1,013	1,071	0	0	0	0	0	0

a. Source: Du Pont, 1982.

sturgeon, are exploited to a limited degree by nonprofessional local fishermen. There is no fishery specifically for hickory shad in South Carolina or Georgia; however, many are taken each year incidental to the catch of American shad (Ulrich et al., 1978).

Sport fishermen are the principal consumers of river fishes, primarily sunfish and crappie. Striped bass, which is classified as a game fish in South Carolina and Georgia (Ulrich et al., 1978), is a favorite quarry of fishermen in the Augusta area.

Commercial and recreational fisheries for blueback herring exist in South Carolina (Ulrich et al., 1978), but none are taken commercially in Georgia because of state netting restrictions.

Although species of commercial or sport fishing importance in the Savannah River might use SRP streams, DOE does not allow fishing or other exploitation of commercial species.

The Fisheries Section of the Georgia Department of Natural Resources published the results of a creel survey in the estuarine and fresh-water sections of the Savannah River from December 29, 1979 to December 26, 1980 (Georgia Game and Fish Division, 1982). The most abundant species harvested in the fresh-water section were bluegills (29.1 percent), redbreast sunfish (27.5 percent), warmouth (10.6 percent), bullheads (7.1 percent), and crappie (6.2 percent). Those fish species comprising the greatest weight were bluegills (19.8 percent), redbreast sunfish (21.1 percent), warmouth (8.2 percent), largemouth bass (7.3 percent), and crappie (7.0 percent). Based on electrofishing studies conducted by the Georgia Game and Fish Division, the relative abundance of sunfish in the freshwater section of the river is high, as is the actual angler success rate. The success rate for largemouth bass (0.04 percent fish per hour) was low. The average-size striped bass (5.21 kilograms) creeled in fresh water was over four times greater than the average-size striped bass (1.19 kilograms) creeled in the estuary.

The most abundant species harvested in the estuarine section were croakers and spots (24.5 percent), white catfish (17.4 percent), silver perch (11.3 percent), and other species (26.3 percent). Species comprising the greatest weight were white catfish (23.9 percent), red drum (16.0 percent), and sea trout (12.9 percent). Angler success rates for all species were very low.

The greatest fishing effort in the estuary was expended for sea trout (42.1 percent), striped bass (29.9 percent), and red drum (17.3 percent). The five most sought-after species in fresh water were largemouth bass (38.0 percent), sunfish (30.5 percent), redbreast sunfish (12.7 percent), crappie (7.7 percent), and catfish (5.4 percent).

DOE (1987) cites evaluations made of the fishery resources in the Savannah River downstream of the New Savannah Bluff Lock and Dam during 1980-1982. Average annual sport fishing harvest from the freshwater portions of the river (approximately RM 21-187) was estimated to range from 171,561 fish/year in 1982 to 550,282 fish/year in 1980 (3 year averages = 305,778 fish/year). Dominant species in the sport harvest were redbreast sunfish (27.2 percent) and bluegill (24.1 percent, Table C-28). The composite category of bream accounted for 64.0 percent of the total angler catch. The composite category

BB-3
BD-5

of catfish also represented a substantial portion of the sport harvest (14.6 percent), with bullhead spp. (8.2 percent) as the major reported taxon within this category. Crappie (8.0 percent) represented a substantial component of the sport harvest and was comparable to warmouth (7.3 percent). No other species (or species group) represented greater than five percent of the sport harvest. Notably, anadromous species (striped bass, 0.2 percent; American shad, 1.7 percent) did not contribute substantially to the angler's harvest. However, American shad harvest may be underestimated because of the development of a fishery for this species near the New Savannah Bluff Lock and Dam, while the assessment for this species emphasized downstream areas of the river.

BB-3
BD-5 The proportions of fish species caught by anglers were frequently in sharp contrast to angler preferences. Approximately 35 percent of angler fishing effort was directed toward bream (composite reporting category plus individual species), while 64 percent of the harvest was from this category (Table C-32). The relationship between effort and harvest was even more disparate for largemouth bass; 25.7 percent of the fishing effort was targeted toward this species, while it constituted only 3.2 percent of the catch. Overall, catfish were not highly desired (approximately 7 percent of effort), but were caught in slightly greater proportion (14.6 percent). American shad (7.8 percent of effort) and striped bass (4.7 percent of effort) were caught in substantially lower abundances than desired by sport fishermen, the disparity being comparable to that exhibited for largemouth bass.

Impingement relative abundances for all taxa of catfish [bullhead spp. (2.1 percent), channel catfish (0.8 percent) and white catfish (1.3 percent)] were lower than relative abundances for those taxa in the creel (8.2 percent, 4.2 percent, and 2.1 percent, respectively Figure C-9). However, the relative abundances of these taxa in hoop-net collections from the river were substantially higher than for either impingement or angler catches. The disparity between relative abundances of catfish taxa in electrofishing and hoop-net collections suggests that catfish are a substantial component of the Savannah River ichthyofauna, and that electrofishing provides poor estimates of the abundance of these taxa.

American shad, striped bass and hybrid bass were minor components in all the collection methods (angling, electrofishing, hoop-netting, impingement, Figure C-9). The abundance of the migratory American shad and striped bass in the Savannah River near SRP was undoubtedly underestimated during the quarterly sampling program. Nevertheless, the low frequency of these species in impingement collections (approximately 100 collections throughout the year) is highly encouraging because it indicates that adults and juveniles of these species are minimally influenced by impingement mortality associated with SRP operations.

C.8 HABITAT EVALUATION PROCEDURES ANALYSIS

BD-4 The potential effects on wildlife of the implementation of thermal mitigation alternatives for C- and K-Reactors were evaluated using Habitat Evaluation Procedures (HEP) developed by the U.S. Fish and Wildlife Service (FWS) and modified by the Savannah River Laboratory for the Savannah River Plant (SRP) environment (Mackey et al., 1987). These procedures allow for the relative

Table C-32. Fishes Preferred and Caught by Savannah River Sport Fishermen^a

Taxon	Percent Angler Effort	Percent Angler Catch
Bream	24.9	64.0 ^b
Redbreast sunfish	8.7	27.2
Bluegill	1.0	24.1
Warmouth	0.1	7.3
Redear sunfish	0.4	4.4
Largemouth bass	25.7	3.2
Crappie	10.7	8.0
Yellow Perch	1.3	3.0
Catfish	7.0	14.6 ^b
Bullhead spp.	0.4	8.2
Channel catfish	<0.1	4.2
White catfish	0.5	2.1
Chain pickerel	0.5	0.9
American shad	7.8	1.7
Striped bass	4.7	0.2
Hybrid bass	4.4	0.3
Other	1.9	4.1
Total	100.0	100.0

a. Source: DOE, 1987.

b. Sum of taxa within category.

BB-3
BD-5

ranking of project alternatives and/or mitigation with respect to representative wildlife species over the life of the project or for selected time periods in the future. The Department of Energy-Savannah River was requested by the FWS to provide an HEP analysis for the cooling water alternative for these reactors during the comment period on the Draft EIS.

For C- and K-Reactors the potential wildlife impacts and/or benefits of once-through and recirculating cooling towers were evaluated for both near-term (30-year) and long-term (100-year) time periods. These options were evaluated against the projected effects of the current operations, i.e., release of once-through cooling water effluent directly to Four Mile Creek and Pen Branch from C- and K-Reactors, respectively. Those species that were selected as representative of potential project effects in terrestrial environments included the pine warbler, downy woodpecker, cottontail rabbit, gray squirrel, white-tailed deer, and eastern wild turkey. Those species selected to represent aquatic and/or semi-aquatic environments included the creek chub, redbreast sunfish, black bullhead catfish, blueback herring, great egret, wood duck, mallard, and yellow-bellied slider. The land cover data base for the habitat cover maps for the HEP assessment was developed using Geographic Information System (GIS) methods and remote sensing aerial photography and multispectral scanner data. Much of the data to predict future changes in Four Mile Creek, Pen Branch, and the SRP Savannah River swamp was

BD-6

developed from previous remote sensing studies and from the Comprehensive Cooling Water Study (CCWS) and L-Reactor restart studies.

BD-4

For the various cooling water alternatives, the following relative rankings of future wildlife effects were determined. Effects on terrestrial wildlife from construction of the once-through and recirculation cooling towers are essentially equal since in both cases either type of tower would be constructed at the same location and pipeline and other support facilities would affect essentially the same locations. Small stream species, such as the creek chub, benefit more from the recirculation alternative in the upper reaches of the creeks. In the middle and lower reaches, species such as the catfish and sunfish benefit more from the once-through alternative. In the deep swamp environment, those fish which are more likely to use the swamp during the spawning period benefit more from the recirculation alternative. In the Savannah River swamp, wading birds such as the great egret benefit more from the recirculation alternative. Overwintering waterfowl such as the mallard benefit more either from the present SRP operations or from the once-through cooling tower. These alternatives either maintain the existing "marsh" type environment in the swamp for wintering waterfowl or permit expansion of this type of habitat as deep swamp wetlands (cypress/tupelo) are reduced and converted to more open wetlands by the future release of high flows of cooling water effluent. Similar trends were noted for both C- and K-Reactors for both the short-term 30-year and long-term 100-year analyses.

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APPENDIX D

RADIOCESIUM INVENTORY AND TRANSPORT AND ATMOSPHERIC TRITIUM RELEASES

This appendix discusses the existing releases of radionuclides, principally radiocesium, to the Beaver Dam Creek, Four Mile Creek, and Indian Grave Branch/Pen Branch systems; describes the estimated distribution and inventory of radiocesium in the sediments, fish, and water of the creeks, swamp, and Savannah River; examines the transport of radiocesium offsite; and predicts the concentrations in the Savannah River and downstream water-treatment plants as a result of implementation of the alternative cooling water systems. This appendix also describes the atmospheric releases of tritium associated with the discharge of cooling water from existing and alternative cooling water systems.

D.1 RELEASES OF RADIOCESIUM

The principal sources of radiocesium in the environment at the Savannah River Plant have been reactor effluent discharges to onsite streams and releases from the chemical separations facilities in F- and H-Areas. From 1955 through 1980, about 560 curies of radiocesium were discharged to all onsite streams (DOE, 1984a).

From 1960 through 1980, approximately 21.9 and 16.2 (both decay corrected to 1980) curies of cesium-137 were discharged to Indian Grave Branch/Pen Branch and Four Mile Creek from K- and C-Reactors, respectively (Table D-1). These discharges resulted from leaching of reactor fuel elements with cladding failures that exposed the underlying fuel to water. The direct sources of these releases were heat-exchanger cooling water, spent-fuel storage and disassembly-basin effluents, and process water from K- and C-Reactor areas. In addition to these reactor effluent discharges, approximately 0.7 curies of cesium-137 (decay corrected to 1980) was released to Four Mile Creek from the chemical separations facilities in F- and H-Areas, and 21.9 curies (decay corrected to 1980) of cesium-137 was released to Four Mile Creek as a result of an overflow of high-level waste in 1967. Generally, the longer lived cesium-137 will be of greater interest than cesium-134. A cesium-134 to cesium-137 ratio of 1:20 is expected (DOE, 1984a) in creek sediments. Further, special low-level analyses of water samples from the Savannah River have not detected cesium-134 attributable to Plant releases since the program was initiated in March 1983 (Hayes, 1986). When the change in radionuclide transport due to operation of the alternative cooling water systems is considered, both forms of cesium are identified.

Through 1980, releases of radiocesium to Beaver Dam Creek amounted to only 0.004 curie (decay corrected). These small releases occurred from the D-Area heavy-water production facility (Du Pont, 1985a). A summary of releases through 1980 to Beaver Dam Creek is also presented in Table D-1.

Table D-1. Radiocesium Releases (Ci) 1960 Through 1980^{a, b}

Creek	Radionuclide	Source	Total release	Total release, decay corrected to 1980
Indian Grave Branch/ Pen Branch	Cs-134	K	0.19	0.03
	Cs-137	K	24.442	16.2
		Total:	24.63	Total: 16.23
Beaver Dam Creek	Cs-134	D	-	-
	Cs-137	D	-	0.004
				Total: 0.004
Four Mile Creek	Cs-134	C	0.063	0.01
	Cs-137	C	31.092	21.9
	Cs-137	F	0.632	0.53
	Cs-137	H	0.206	0.18
	Cs-137	H ^c	41.160	30.8
		Total:	73.15	Total: 53.42

a. Du Pont, 1985a.

b. All releases are direct liquid releases to onsite streams.

c. In 1967, overflow of high-level waste to ground and nearby storm sewer occurred when flow from 242-H evaporator to Tank 9 was restricted by formation of crystals.

D.2 DISTRIBUTION OF RADIOCESIUM

D.2.1 SEDIMENTS

Most of the cesium-137 that has been discharged to onsite creeks by SRP operations and fallout from offsite weapons testing became associated with the silts and clays found in the streambed and suspended solids. The principal mechanisms for this association were (1) cation and sorption processes exchange with kaolinite and gibbsite clay minerals, and (2) chelation with naturally occurring organic material. Table D-2 shows the variation in sand, silt, and clay content; total carbon content; and ion exchange capacity in sediment depth increments of 0-5 and 5-10 centimeters in floodplain soils of the three creeks (Du Pont, 1985a). A distribution coefficient of $K_d = 3960$, measured for sediments from Four Mile Creek and Steel Creek (Kiser, 1979), and the work by Prout (1958) demonstrate the affinity of cesium-137 for the sediments and suspended solids in the creek systems.

As a result of these affinities, sedimentation and sorption processes control the distribution of cesium-137 within the creeks and deltas and the adjoining Savannah River swamp. The resuspension, transport, and deposition of sediment are governed by the hydraulic properties of the sediment and streambeds and by the creeks' flow regimes.

Table D-2. Results of Floodplain Sediment-Characterization Analysis for Beaver Dam Creek, Four Mile Creek, and Indian Grave Branch/Pen Branch^a

Creek	Location/ depth increment	Composition (%)			Total organic carbon (%C)	Cation- exchange capacity (meq/100g)
		Sand	Silt	Clay		
Indian Grave Branch/ Pen Branch	Road 3					
	0-5 cm	61	20	19	7.4	3.8
	5-10 cm	75	14	11	6.2	3.8
	Indian Grave Branch at Road B					
	0-5 cm	19	60	21	1.3	5.8
	5-10 cm	19	60	21	0.9	4.1
	Swamp between Four Mile Creek and Pen Branch					
	0-5 cm	23	43	34	7.1	13.4
	5-10 cm	17	37	46	5.0	11.9
	Delta					
	0-5 cm	15	48	37	4.7	13.2
	5-10 cm	49	28	23	3.3	9.7
	Stave Island					
	0-5 cm	72	6	22	24.1	17.3
	5-10 cm	68	11	21	18.0	15.6
Beaver Dam Creek	Downstream of D-Area effluent					
	0-5 cm	39	42	19	8.7	7.5
	5-10 cm	51	36	13	10.4	2.3
	Road A-12.2 South					
	0-5 cm	40	24	36	11.4	7.6
	5-10 cm	17	26	57	5.9	8.0
	Mouth					
	0-5 cm	17	53	30	2.1	11.7
	5-10 cm	41	32	27	1.2	7.7
Four Mile Creek	Road 3					
	0-5 cm	79	12	9	7.1	7.8
	5-10 cm	90	4	6	2.4	2.5

Table D-2. Results of Floodplain Sediment-Characterization Analysis for Beaver Dam Creek, Four Mile Creek, and Indian Grave Branch/ Pen Branch^a (continued)

Creek	Location/ depth increment	Composition (%)			Total organic carbon (%C)	Cation- exchange capacity (meq/100g)
		Sand	Silt	Clay		
Four Mile Creek (continued)	Road A					
	0-5 cm	33	42	25	0.1	10.1
	5-10 cm	33	29	38	0.3	11.2
	Delta					
	0-5 cm	34	42	24	5.5	10.9
	5-10 cm	46	28	26	2.6	6.2
	Mouth					
	0-5 cm	52	29	19	1.9	15.9
	5-10 cm	51	28	21	1.2	13.5

a. Du Pont (1985a).

Almost all sediment redistribution occurred between 1955 and 1968, the period of major reactor discharges. Since 1968, little change has occurred in the sedimentation patterns or in the channel-delta configurations (Ruby, Reinhart, and Reel, 1981).

D.2.1.1 Beaver Dam Creek Sediments

Concentrations of cesium-137 in Beaver Dam Creek sediments are presented in Table D-3. Cesium-137 concentrations ranged from 0.20 picocurie per gram at the south arm near Road A-12.2 to 1.13 picocurie at the mouth. These concentrations are very low compared to data from the other onsite streams.

D.2.1.2 Four Mile Creek Sediments

Cesium-137 has been monitored routinely in Four Mile Creek sediments since 1977. These data are presented in Table D-4 (Du Pont, 1985a,b). Sediment cesium-137 concentrations along Four Mile Creek ranged from 0.4 to 20.3 (mean = 8.6) picocuries per gram, dry weight, at the creek-swamp confluence and from 11 to 80.3 (mean = 35.3) picocuries per gram, dry weight, at Road A-7 upstream of thermal influence. In general, concentrations at both Four Mile Creek stations clearly reflected SRP releases, while Savannah River floodplain sediment concentrations downstream of Four Mile Creek were within ranges associated with global fallout as high as 1.0 picocurie per gram.

Table D-3. Concentrations of Cesium-137
(pCi/g, Dry Weight) in Beaver
Dam Creek Sediments^a

Core location	Concentration
Below 400-D	(b)
South Arm Road A-12.2	0.20
Mouth	1.13

a. Du Pont, 1985a.

b. Not detectable above background.

D.2.1.3 Pen Branch/Indian Grave Branch Sediments

Cesium-137 has been monitored routinely in Pen Branch/Indian Grave Branch sediments since 1977. Table D-5 presents these data (Du Pont, 1985a,b). Because the Pen Branch flow joins the flow of Steel Creek before its entry into the Savannah River, the routine floodplain sediment-monitoring stations at the Steel Creek mouth and in the Savannah River downstream of Little Hell Landing were used for data analysis for both the Pen Branch and Steel Creek systems (Du Pont, 1985a).

D.2.1.4 Swamp and Savannah River Sediments

Beginning in 1974, comprehensive radiological surveys were made of the Savannah River swamp, including the 1235-acre, uninhabited, privately owned Creek Plantation Swamp (Figure D-1), and of the soil and the vegetation. Soil cores collected in 1974 showed that about 70 percent of the cesium-137 was confined to the upper 6 to 7 centimeters but that cesium was detectable at depths of 25 centimeters (Ashley and Zeigler, 1975). The 1982 values were appreciably less than those for 1974, but slightly lower on the average than those for 1977. Mean values at comparable locations averaged 33.3 (1982), 39.8 (1977), and 75.9 picocuries per gram (1974) (Du Pont, 1983b).

D.2.1.5 Savannah River Sediments

In 1974, riverbed sediments from downstream of the Savannah River Plant contained average radiocesium concentrations from about 2 picocuries per gram at the U.S. Highway 301 bridge (River Mile 118.7) near Millhaven, Georgia, to 6.5 picocuries per gram at the Georgia Highway 119 bridge (River Mile 61.5) near Clio, Georgia. Table D-6 summarizes more recent monitoring data for Savannah River sediments.

D.2.1.6 Beaufort-Jasper Water Treatment Plant Sediments

A radiological survey of the raw-water and backwash holding-pond sediments at the Beaufort-Jasper water treatment plant was performed in November 1982

Table D-4. Concentrations of Cesium-137 (pCi/g, Dry Weight)
in Four Mile Creek Sediments

Source	Location (sampling year)	Concentrations
Du Pont, 1985a ^a	Road A-7 (1984)	70.6
	Road 3 (1984)	43.3
	C-Reactor effluent (1984)	0.26
	Road A (1984)	28.8
	Road A-12.21 (1984)	24.1
	Road A-12.2 (1984)	6.9
	Swamp entrance (1984)	10.5
	Swamp entrance (1984)	10.4
	Swamp entrance (1984)	10.3
	Swamp entrance (1984)	29.0
	Mouth (1984)	0.53
	Mouth (1984)	0.79
	Road A-7 (1977-1983)	35.2 ± 55.0 ^b
	Four Mile Creek Swamp (1977-1983)	8.6 ± 15.9
	Savannah River downstream of Four Mile Creek (1977-1983)	0.4 ± 0.5
Du Pont, 1985b	Road A-7 (1984)	18 ± 0.18 ^c
	A-7A, Beaver Pond (1984)	49 ± 0.60
	Discharge at swamp (1984)	0.5 ± 0.02

a. Du Pont, 1985a; these data are grouped into two categories. The first 12 entries are one-time samples, each 7.6 centimeters deep and 15.2 centimeters wide, collected in 1984. The last six entries are 7-year averages of floodplain sediment samples. These are 7.6-centimeter-deep multiple samples composited for analysis that were collected between 1977 and 1983.

b. Error term is 2 standard deviations of 7-year mean.

c. Error term is 2-sigma counting error.

(Du Pont, 1985a). Cesium-137 concentrations in the sediment from the raw-water holding pond are about one-tenth those from the backwash pond sediment, which is principally floc. Backwash floc from the North Augusta water treatment plant, which is upriver from the Plant, has cesium-137 concentrations similar to those at the Beaufort-Jasper plant. These cesium-137 concentrations are low, generally less than 1 picocurie per gram, and within the concentration range of cesium-137 in sediments from other locations in South Carolina not influenced by the Savannah River Plant (Hayes, 1983a).

Table D-5. Concentrations of Cesium-137 (pCi/g, Dry Weight)
in Indian Grave Branch/Pen Branch Sediments

Source	Location (sampling year)	Concentrations
Du Pont 1985a ^a	Road B-3 (1984)	0.10
	K effluent at Road B on Indian Grave Branch (1984)	0.6
	Road A-13.1 (1984)	7.7
	Road A-13.2 (1984)	0.10
	Swamp along Road A-13 (1984)	2.2
	Swamp along Road A-13 (1984)	5.0
	Swamp entrance (1984)	0.31
	Swamp entrance (1984)	0.57
	Swamp entrance (1984)	0.72
	Swamp entrance (1984)	0.31
	Swamp near Stave Island (1984)	1.3
	Swamp near Stave Island (1984)	0.43
	Pen Branch discharge at swamp (1977-1983)	4.2 ± 6.5^b
	Steel Creek-Pen Branch Mouth (1977-1983)	14.4 ± 46.3
	Savannah River downstream of Little Hell Landing (1977-1983)	2.7 ± 7.9
Du Pont, 1985b	Pen Branch discharge at swamp (1984)	0.3 ± 0.02^c

a. Du Pont, 1985a; these data are grouped into two categories. The first 12 entries are one-time samples, each 7.6 centimeters deep and 15.2 centimeters wide, collected in 1984. The last six entries are 7-year averages of floodplain sediment samples. These are 7.6-centimeter-deep multiple samples composited for analysis that were collected between 1977 and 1983.

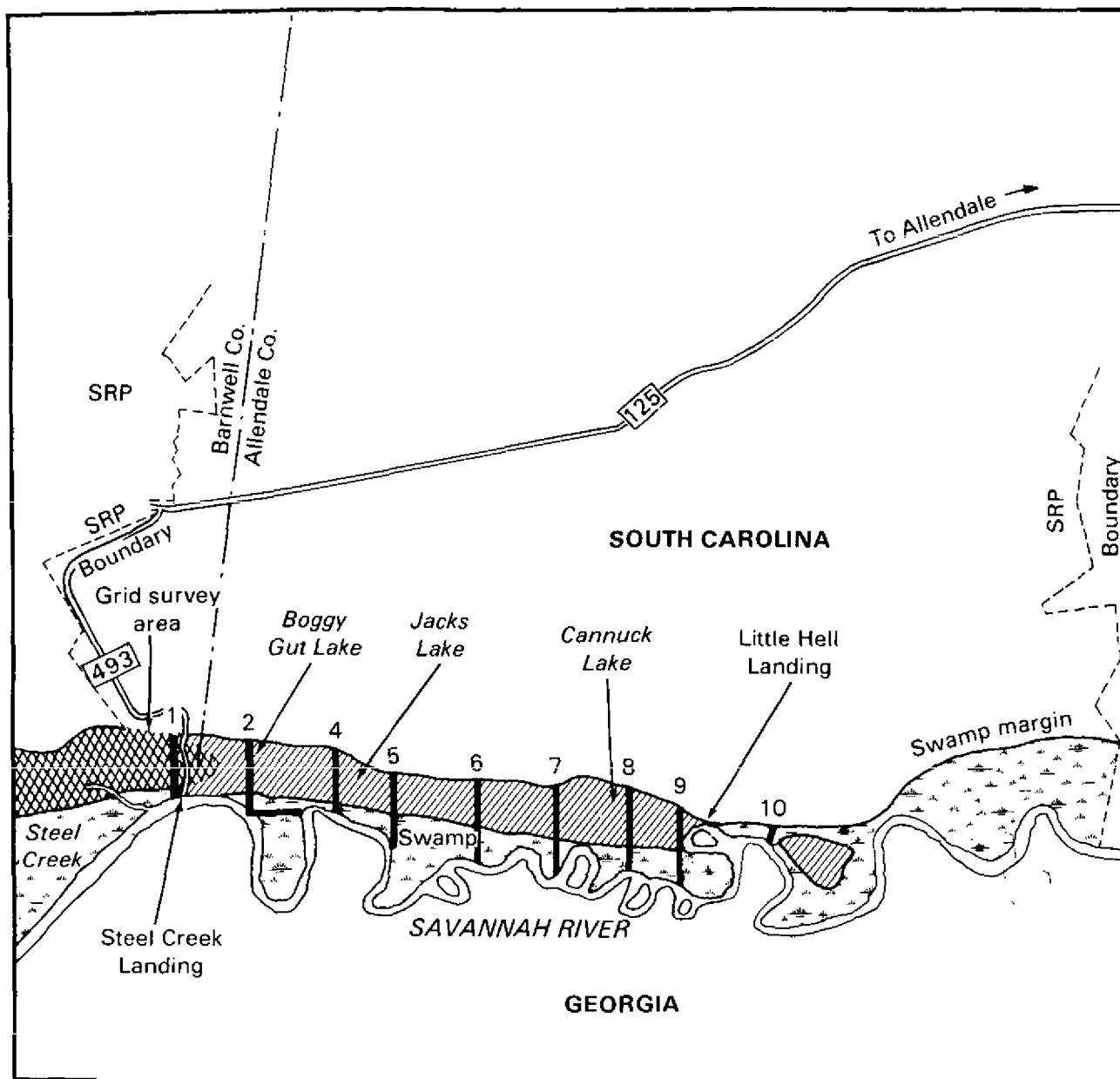
b. Error term is 2 standard deviations of 7-year mean.

c. Error term is 2-sigma counting error.

D.2.2 BIOTA

When K- and C-Reactors are not operating, the Pen Branch and Four Mile Creek delta areas provide roosting and feeding habitat for migratory ducks. The cesium-137 concentration in flesh from these ducks is expected to reflect their cesium-contaminated environment (Marter, 1974; Fendley, 1978).

Whole-body bioaccumulation factors for fish taken from the river at the U.S. Highway 301 bridge from 1965 to 1970 average about 2903 picocuries per gram



Legend:

-  Detectable Cs-137 deposition
-  Area of highest Cs-137 deposition

Total contaminated offsite area is 940 acres

Source: Du Pont, 1983a

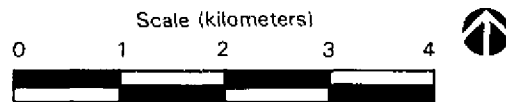


Figure D-1. Locations of Transects Used for Collecting Soil Cores and Vegetation Samples in Savannah River Swamp, Including 1235-acre Creek Plantation Swamp

Table D-6. Cesium-137 Concentrations (pCi/g, Dry Weight) in Savannah River Sediments (0-8cm depth)^a

Location	River mile	Average, 1975-1979	1980	1981	1982	1983	1984
Demier's Landing ^b	160.5	0.5	0.2	0.07	0.03	0.13	0.21
Downriver of Four Mile Creek	150.2	0.7	0.2	0.4	0.25	0.20	(d)
Upriver of Little Hell Landing	136.6	0.8	0.2	0.7	0.7	0.25	0.34
Downriver of Little Hell Landing	134.0	3.9	0.4	0.5	0.1	0.39	0.37
Upriver of Lower Three Runs Creek	129.5	0.8	0.4	0.5	(d)	0.32	0.76
U.S. Highway 301 bridge	118.7	1.7	1.1	0.07	0.5	0.50	(d)
GA Highway 119 bridge	61.5	6.5 ^c	(d)	(d)	(d)	(d)	(d)

a. Sources: Ashley and Zeigler, 1976, 1978a,b, 1981; DOE, 1984a.

b. Control above plant.

c. Based on 1975 data only.

d. No analysis performed.

(Table D-7). The mean bioaccumulation factor for 20 species of fish (527 specimens) from Steel Creek was found to be 2019 whole-body and 3029 flesh (Smith, Sharitz, and Gladden, 1982a,b; Ribble and Smith, 1983). A fish flesh bioaccumulation factor of 3000, 1.5 times the value recommended in the NRC LADTAP-II computer code (Simpson and McGill, 1980), was chosen for dose-assessment analyses in this document.

D.2.3 WATER

D.2.3.1 Beaver Dam Creek

Based on the low concentration of cesium-137 in Beaver Dam Creek sediment and the nature of operations in D-Area, which do not involve cesium-137, the concentration in water is expected to be negligible.

D.2.3.2 Four Mile Creek

Annual mean cesium-134 and cesium-137 concentrations in Four Mile Creek water (nominally based on 12 measurements per year at Road A) are presented in Table D-8. From 1978 to 1986 the annual mean concentrations remained low, ranging from 0.45 to 2.4 picocuries per liter and from 0.30 to 1.6 picocuries per liter for cesium-134 and cesium-137, respectively. However, the individual measurements exhibit considerable variability, with standard deviations typically ranging from about 1 to 2 times their respective annual mean value. In addition, the 95 percent confidence limit for the counting error was usually several times the reported value.

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Table D-7. Radiocesium Whole-Body Bioaccumulation Factors for Fish from Steel Creek and Savannah River^a

Year	Steel Creek (Road A)		Savannah River ^b	
	Maximum	Average	Downriver of Steel Creek	Hwy 301 bridge
1965	-- ^c	--	1626	3902
1966	--	--	1975	1111
1967	--	--	5528	1707
1968	2385	1355	4058	2174
1969	5490	2353	4848	7273
1970	3958	1639	1111	1250
1981	3792 ^d	2019 ^e	--	--
Arithmetic mean		1842	3191	2903
Geometric mean		1802	2700	2295

- a. Adapted from Marter, 1970a,b; Du Pont, 1982; and Smith, Sharitz, and Gladden, 1982a,b.
b. Values are averages.
c. Data not available.
d. Mean of 53 specimens of largemouth bass, for which maximum whole-body bioaccumulation factors were measured in 1981. Maximum bioaccumulation factor measured for largemouth bass was 4780. One specimen of American eel had a bioaccumulation factor of 8300.
e. Mean of 527 specimens representing 20 species.

The cesium-134 data are suspect because the reported concentrations of cesium-134 are greater than the cesium-137 concentrations. A cesium-134 to cesium-137 ratio of 1:20 is expected (DOE, 1984a). Further, special low-level analyses of water samples from the Savannah River have not detected cesium-134 attributable to Plant releases since the program was initiated in March 1983 (Hayes, 1986).

D.2.3.3 Pen Branch/Indian Grave Branch

Table D-8 also lists the cesium-134 and cesium-137 concentrations for Pen Branch/Indian Grave Branch. Ranges similar to those for Four Mile Creek were observed. From 1978 to 1986, annual mean concentrations ranged from 1.0 to 2.0 picocuries per liter and from 0.12 to 1.6 picocuries per liter for cesium-134 and cesium-137, respectively. As noted in Section D.2.3.2, the data exhibit considerable variability and the 95-percent confidence limits for the counting error were typically several times the measured values. The cesium-134 data are suspect for the reasons stated in Section D.2.3.2.

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Table D-8. Annual Mean Concentrations of Cesium-134 and Cesium-137 (pCi/liter) in Water of Four Mile Creek and Indian Grave Branch/Pen Branch^a

Creek	Location	Annual Mean Concentration (pCi/L) ^b								
		1978	1979	1980	1981	1982	1983	1984	1985	1986
Pen Branch	Road A									
Cesium-134		1.4	(c)	(c)	1.2	1.0	2.0	1.4	1.7	(c)
Cesium-137		0.26	(c)	(c)	0.40	0.53	1.6	0.12	0.42	(d)
Four Mile Creek	Road A									
Cesium-134		0.78	(c)	(c)	0.77	0.45	1.3	1.4	2.4	(c)
Cesium-137		0.48	(c)	(c)	0.58	0.30	1.6	0.65	0.43	(d)

- a. Sources: Ashley et al., 1982; Zeigler, Culp, and Smith, 1983; Ashley, Padezanin, and Zeigler, 1984a; Du Pont, 1985b; Ashley and Zeigler, 1981, 1984; Zeigler, Lawrimore, and Heath, 1986; Zeigler, et al., 1987.
- b. Mean values were below the minimum detectable concentration for cesium, using standard techniques.
- c. No value reported.
- d. Not detected.

D.2.3.4 Savannah River

The concentrations of cesium-137 in the Savannah River have been monitored routinely since 1960. The highest concentrations were measured in the early 1960s as a result of SRP releases and nuclear weapons test fallout (Figure D-2). Radiocesium concentrations are diluted as the flow of the Savannah River increases downriver from the Savannah River Plant, and as these radionuclides are deposited in the river channel and floodplain (Hayes and Boni, 1983).

Results of recent special low-level cesium-137 measurements of Savannah River water samples are presented in Table D-9. In 1983, prior to the restart of L-Reactor, the concentration of cesium-137 in the river attributable to the Savannah River Plant was 0.046 picocurie per liter (difference between upriver and downriver average values). With a total river flow at the Highway 301 Bridge (the downriver monitoring station) of 1.189×10^{13} liters during 1983 (Du Pont, 1984a), the annual release of cesium-137 to the river from the Plant was calculated to be about 0.55 curie. In 1984 the releases totaled about 0.57 curie, following the same calculation methodology (Table D-9 and Du Pont, 1985b).

D.2.3.5 Water-Treatment Plants

The North Augusta, South Carolina, water-treatment plant is about 20 River Miles above the Savannah River Plant. There are no known individuals who consume Savannah River water for a distance of about 120 River Miles downriver of

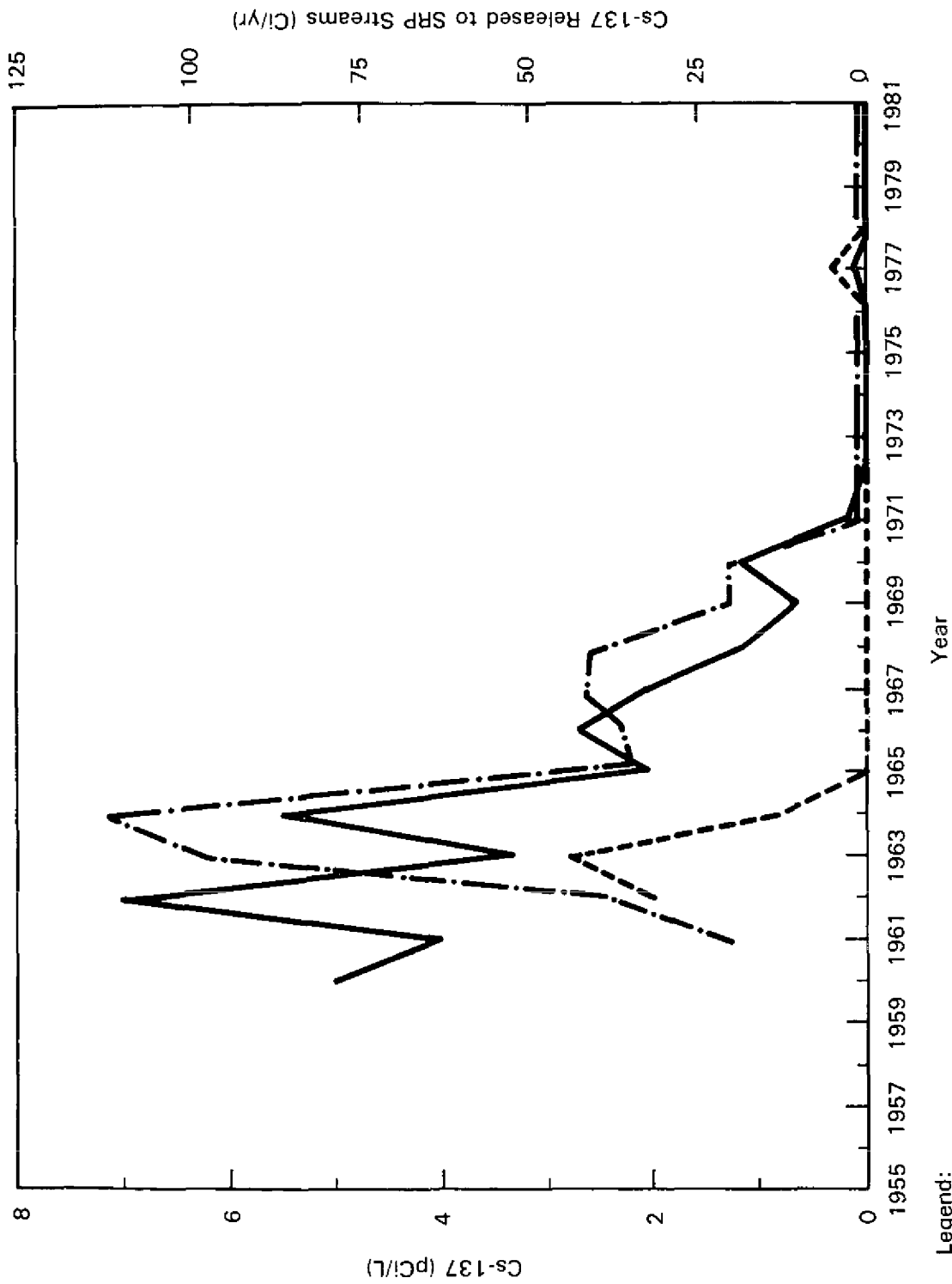


Figure D-2. Cesium-137 Concentrations in the Savannah River, 1960-1980

Source: Hayes and Boni, 1983

Table D-9. Special Low-Level Cesium-137 Measurements in Water^a

Concentration, pCi/L					
Location	Year	No. of Analyses ^b	Maximum ^c	Minimum ^c	Average ^d
<u>Savannah River</u>					
Shell Bluff (Upriver)	1983	11	0.024 ± 0.005	0.012 ± 0.006	0.017 ± 0.008
	1984	37	0.029 ± 0.003	0.004 ± 0.001	0.012 ± 0.011
	1985	28	0.032 ± 0.004	0.007 ± 0.002	0.015 ± 0.007
	1986	23	0.035 ± 0.002	0.007 ± 0.001	0.021 ± 0.007
Highway 301 (Downriver)	1983	13	0.113 ± 0.016	0.035 ± 0.010	0.063 ± 0.042
	1984	51	0.106 ± 0.007	0.031 ± 0.002	0.065 ± 0.037
	1985	28	0.211 ± 0.010 ^e	0.023 ± 0.006	0.071 ± 0.038
	1986	46	0.213 ± 0.004	0.057 ± 0.002	0.114 ± 0.038
<u>Water Treatment Facility</u>					
Port Wentworth, GA Raw	1983	21	0.057 ± 0.008	0.023 ± 0.006	0.045 ± 0.017
	1984	28	0.037 ± 0.005	0.022 ± 0.004	0.032 ± 0.010
	1985	15	0.069 ± 0.003	0.016 ± 0.003	0.049 ± 0.031
	1986	19	0.098 ± 0.003	0.022 ± 0.002	0.064 ± 0.016
Port Wentworth, GA Finished	1983	33	0.048 ± 0.009	0.020 ± 0.004	0.036 ± 0.019
	1984	31	0.035 ± 0.006	0.017 ± 0.020	0.026 ± 0.011
	1985	18	0.060 ± 0.003	0.013 ± 0.005	0.036 ± 0.022
	1986	23	0.089 ± 0.006	0.023 ± 0.002	0.051 ± 0.015
Beaufort-Jasper, SC Raw	1983	19	0.066 ± 0.014	0.019 ± 0.007	0.042 ± 0.027
	1984	31	0.052 ± 0.001	0.020 ± 0.004	0.031 ± 0.022
	1985	14	0.144 ± 0.025 ^f	0.018 ± 0.005	0.043 ± 0.063
	1986	22	0.080 ± 0.003	0.040 ± 0.005	0.063 ± 0.011
Beaufort-Jasper, SC Finished	1983	33	0.039 ± 0.006	0.013 ± 0.005	0.024 ± 0.015
	1984	28	0.024 ± 0.006	0.009 ± 0.002	0.016 ± 0.010
	1985	15	0.022 ± 0.002	0.008 ± 0.002	0.013 ± 0.009
	1986	21	0.044 ± 0.004	0.006 ± 0.002	0.020 ± 0.010

a. Adapted from DOE 1987.

b. Represents number of times analyses were performed on samples obtained from continuous samplers.

c. ± value is the 2 sigma counting uncertainty.

d. ± value is the 2 sigma standard deviation about the mean.

e. These slightly higher Cs-137 concentrations occurred the first month after L-Reactor restart on October 31, 1985.

f. Occurred in April during construction activities in the canal between the river and water treatment plant.

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the Plant. At this distance (River Mile 39.2) and beyond (River Mile 29.0) are the Beaufort-Jasper and Cherokee Hill water-treatment plants, respectively. The Beaufort-Jasper water-treatment plant pumps water from the river through a 2.4-kilometer-long inlet canal that connects to an open canal. This open, unlined canal flows 29 kilometers to the water-treatment plant (Du Pont, 1983a). The Cherokee Hill water-treatment plant pumps water from the Savannah River above the U.S. Interstate Highway 95 bridge; the water is piped about 11 kilometers to the plant (Du Pont, 1983a).

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A special program was initiated in March 1983 to measure the effect of L-Reactor restart on the cesium-137 and cobalt-60 concentrations in the raw and finished water in the downriver water treatment plants (Beaufort-Jasper and Cherokee Hill). The concentrations of these two radionuclides are so low in the raw and finished water that samples of 300-400 liters were required. A special resin was used to concentrate the radionuclides. Analysis was performed in an ultra low-level counting facility; counting was performed for about 16 hours (Hayes, 1987). Results of these studies for cesium-137 are presented in Table D-9.

D.3 INVENTORY OF CESIUM-137

The decay-corrected inventory of cesium-137 releases to onsite streams from 1960 through 1980 totaled 414.18 curies (Du Pont, 1985a). Most cesium-137 releases to onsite streams during this period originated from L- and P-Reactor areas (to Steel Creek) and R-Reactor area (to Lower Three Runs Creek). Two methods (Table D-10) were used to estimate the inventory of cesium-137 remaining in the onsite streams. The first method (Method 1, Table D-10) is based on the extensive sampling of Steel Creek. Studies of cesium-137 in Steel Creek based on core samples up to 1 meter in length and categorized by soil type, sample depth interval, and creek section identified 67.1 curies (decay corrected to 1981) between the area above L-Reactor and the delta (Smith, Sharitz, and Gladden, 1982a,b). This value is about 33 percent of the amount of cesium-137 released to Steel Creek (201.23 curies). To calculate the estimated inventory of cesium-137 remaining in the other streams, the release values were multiplied by 0.33, assuming that the Steel Creek ratio of remaining cesium-137 to the total amount released is the same for all streams. The second method (Method 2, Table D-10), from the Comprehensive Cooling Water Study (Du Pont, 1985a), uses a mass-balance approach. Using this approach, the amount of cesium-137 (decay corrected to 1980) remaining in an onsite stream was calculated by multiplying the total cesium-137 released to the stream between 1960 and 1980 by about 76 percent, or the ratio of total cesium-137 released to all SRP streams (about 414 curies, decay corrected to 1980) minus the total cesium-137 in transport (about 100 curies, decay corrected to 1980) to the total cesium-137 released to all SRP streams.

The three creeks of concern - Four Mile Creek, Beaver Dam Creek, and Pen Branch/Indian Grave Branch - contain only about 17 percent of the total cesium-137 remaining onsite. This amounts to 23.22 curies if Method 1 is used to derive the estimate.

Table D-10. Cesium-137 Inventory Remaining in Onsite Streams as Estimated by Two Methods^a

Stream	Total release 1960 through 1980 ^b (Ci)	Percent of total release ^c	Method 1 (using Steel Creek sampling data) ^d (Ci)	Method 2 (mass balance approach) ^e (Ci)
Four Mile Creek	53.42	12.9	17.81	40.59
Beaver Dam Creek	0.0	0.0	0.0	0.0
Indian Grave/ Pen Branch	16.23	3.9	5.41	12.27
Total of all SRP streams	414.18	100	138.10	314.65

a. Sources: DOE, 1984a; Du Pont, 1985a.

b. Sum of cesium-134 and cesium-137 activities (Du Pont, 1985a). All values decay corrected to 1980.

c. Total decay-corrected (to 1980) cesium-137 releases from 1960 through 1980.

d. L-Reactor EIS (DOE, 1984a) uses 67.1 curies as the estimate of cesium-137 remaining in Steel Creek. This value is about 33 percent of amount of cesium-137 released to Steel Creek (201.23 curies). Values for other streams were calculated by multiplying release value by 0.33, assuming that the ratio of remaining cesium-137 to the total released for Steel Creek is the same for the other onsite creeks. All values decay corrected to 1980.

e. Values calculated by multiplying percentage of total releases by 314.65 (414.18 - 99.53) curies. All values decay corrected to 1980.

D.4 REMOBILIZATION OF RADIOCESIUM

The amount of cesium-137 transported from onsite streams to the Savannah River resulting from the implementation of the alternative cooling water systems for K- and C-Reactors was estimated on the basis of data from routine monitoring in Four Mile Creek and Pen Branch (Sections D.2.3.2 and D.2.3.3) and detailed monitoring in Steel Creek (Hayes, 1983c; DOE, 1984a; Zeigler et al., 1987). Special low-level monitoring techniques have shown that the Plant is not releasing cesium-134 to the Savannah River. Therefore, the remobilization of cesium-134 is not considered here.

Measurements in Steel Creek at stream flows of about 3.5 cubic meters per second showed that concentrations of cesium-137 in Steel Creek water appeared to be governed by a reequilibration process between the water and the cesium in the creekbed and floodplain sediments. Hence, transport was found to be proportional to creek flow (Hayes, 1983c).

To estimate the remobilization of cesium-137 from Four Mile Creek, Pen Branch, Steel Creek, and Lower Three Runs Creek as the result of the existing cooling water systems, the annual flow volume from each creek was multiplied by the appropriate mean concentration of cesium-137. Because these cesium-137 concentrations were determined by standard techniques and are less than the limits of detection, the cesium transported by the individual creeks and assumed to reach the Savannah River was adjusted so the sum of the creek contributions matched the total contribution from the Plant, as estimated in Section D.2.3.4. As indicated in Table D-11, the transport from the Plant creeks in 1983, based on standard counting techniques, is calculated to total 1.25 curies, with 0.54 curie from Four Mile Creek. However, the total Plant contribution to the River, based on special low-level counting methods, is estimated to be 0.55 curie. Thus, the contribution from Four Mile Creek was reduced to 44 percent $[(0.55/1.25) \times 100 = 44 \text{ percent}]$ of the calculated value of 1.25 curies, or 0.24 curie of cesium-137.

As indicated in Table D-11, the average total stream flows below Road A for Pen Branch and Four Mile Creek are about equal, approximately 3.0×10^{11} liters per year, or 9.75 cubic meters per second. This flow for the existing cooling water systems for K- and C-Reactors is assumed to be the same as that for the once-through cooling-tower alternatives. The recirculating cooling-tower alternatives would have substantially less flow, 1.08 and 1.35 cubic meters per second for K- and C-Reactors, respectively. Thus, cesium-137 remobilization under these alternatives would be approximately 13.8 and 11.1 percent, respectively, of the "full-flow" alternatives.

For K-Reactor, the recirculating cooling-tower alternative would result in a decrease in the release of cesium-137 of about 0.12 curie per year. For C-Reactor, it would result in a decrease in the release of approximately 0.21 curie per year.

Table D-12 lists the estimated amounts of cesium-137 remobilized for each alternative cooling water system, calculated as outlined above.

Condition	Year	Four Mile Creek ^b	Pen Branch ^b	Steel Creek ^b	Lower Three Runs Creek ^b	Total Calculated releases	Savannah River ^c	Adjustment factor
Total flow (10 ¹¹ liters)	1983	3.34	2.43	0.57	0.59		118.900	
Annual mean Cs-137 (pCi/l)		1.60	1.60	3.00	2.50		0.046	
Calculated transport (curies Cs-137)		0.54	0.39	0.17	0.15	1.25	0.550	0.44
Adjusted transport (curies Cs-137)		0.24	0.17	0.07	0.07	0.55		
Total flow (10 ¹¹ liters)	1984	3.31	3.41	0.73	0.70		107.100	
Annual mean Cs-137 (pCi/l)		0.65	0.12	1.40	1.10		0.053	
Calculated transport (curies Cs-137)		0.22	0.04	0.10	0.08	0.44	0.570	1.30
Adjusted transport (curies Cs-137)		0.29	0.05	0.13	0.10	0.57		
Total flow (10 ¹¹ liters)	1985	2.59	3.19	0.41	0.56		80.220	
Annual mean Cs-137 (pCi/l)		0.43	0.42	0.28	0.56		0.056	
Calculated transport (curies Cs-137)		0.11	0.13	0.01	0.03	0.28	0.450	1.61
Adjusted transport (curies Cs-137)		0.18	0.21	0.02	0.05	0.46		
Estimated releases to SR, existing system (curies Cs-137)	Mean 1983-1985	0.24	0.14					
Annual total flow (10 ¹¹ liters)		3.08	3.01					

a. Annual flow (below Road A) and cesium-137 concentration data from Ashley, Padezanin, and Zeigler (1984b); Bennett et al. (1983, 1984, and 1985); Du Pont (1985b); Zeigler, Lawrimore, and Heath (1986); and Zeigler et al. (1987).

b. Cesium-137 concentrations in SRP streams measured by standard techniques; reported values less than the limits of detection.

c. Cesium-137 concentrations in Savannah River measured by special low-level techniques; annual average concentrations attributable to SRP operations determined by subtracting downriver average from the upriver average (see Table D-9).

Table D-12. Estimated Cesium-137 Releases to Savannah River from C- and K-Reactors in First Year for Each Cooling Water Alternative

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Alternative	Reactor	Release to River (Ci)	Change in release (Ci)
Recirculating cooling towers	K ^a	0.02	-0.12
Once-through cooling tower, ^b existing system to Indian Grave Branch	K	0.14	0.0
Recirculating cooling tower	C ^c	0.03	-0.21
Once-through cooling tower, ^b existing system to Four Mile Creek	C	0.24	0.0

a. Discharges from K-Reactor flow into Indian Grave Branch/Pen Branch.

b. Either a mechanical- or a natural-draft once-through cooling-tower that receives its water by pumping or gravity feed.

c. Discharges from C-Reactor flow into Four Mile Creek.

D.5 TRITIUM AND OTHER RADIONUCLIDE RELEASES

D.5.1 TRITIUM RELEASES AND INVENTORY

Tritium accounts for more than 99 percent of the radioactivity in the Savannah River. From 1960 through 1978, about 1.4×10^6 curies of tritium of SRP origin were in transport in the Savannah River. The peak tritium concentration in river water downstream of the Plant was 14 picocuries per milliliter, recorded in 1961 and 1963. A summary of tritium concentration data appears in Table D-13.

The sources of tritium in liquid effluents include direct release from SRP facilities (42 percent) and migration of tritium from the burial ground, F- and H-Area seepage basins, and the K-Area containment basin (58 percent) (Du Pont, 1984a). Migration occurs when tritium that has been released to the basin in previous years reaches SRP streams via groundwater that outcrops into the streams. Tritium migrating from the C-Area seepage basins has not been detected.

Table D-14 presents the tritium releases through 1980 for individual streams. Tritium monitoring data indicate that essentially all tritium released from the Plant in liquid effluents moves down SRP streams to the Savannah River (Du Pont, 1984a, 1985b).

Table D-13. Average Tritium Concentrations (pCi/ml) in Four Mile Creek, Beaver Dam Creek, Indian Grave Branch/Pen Branch, and Savannah River^a

Location	Concentration								Average
	1953-1981	1978	1979	1980	1981	1982	1983	1984	
Beaver Dam Creek effluent		47	28	34	38	73	69	50	48.4
Four Mile Creek Road A		200	96	80	61	61	58	61	88.1
Indian Grave Branch/ Pen Branch									
K effluent		2.1	23	7.1	3.6	7.8	19	7.6	10.0
Road A		38	46	31	35	32	29	32	34.7
Savannah River									
Above Plant	1.04	0.39	0.38	0.39	0.21	0.36	0.31	0.33	0.34
Above Four Mile Creek	(b)	1.9	1.6	1.4	2.9	3.2	2.5	2.5	2.3
Highway 301	7.55	3.9	3.1	3.2	4.1	4.3	3.3	3.3	3.6

a. Sources: Ashley and Zeigler, 1981; Zeigler, Culp, and Smith, 1983; Ashley, Padezanin, and Zeigler, 1984a,b; Du Pont, 1985a,b; Ashley et al., 1982.

b. Not analyzed.

Table D-14. Tritium Releases to Four Mile Creek, Beaver Dam Creek, and Indian Grave Branch/Pen Branch Through 1980^a

Creek	Source ^b	Release (Ci)
Four Mile Creek	C	249,380
	F	260
	F sbm	39,324
	H	1,172
	H sbm	<u>98,432</u>
	Total	388,568
Beaver Dam Creek	D ^c	124,090
Indian Grave Branch/ Pen Branch	K	212,180
	K sbm	<u>145,390</u>
	Total	357,570

a. Du Pont, 1985a.

b. sbm = seepage basin migration. Entries not so labeled represent areas of direct liquid releases.

c. Releases were from D-Area heavy-water production facility.

Tritium releases to the Savannah River have decreased significantly since the early 1960s when the maximum tritium releases occurred (Du Pont, 1985a,b). The following process control improvements have caused the reduction:

- The elimination of a continuous purge from the reactor-area disassembly basins in the late 1960s, which allowed longer holdup time for tritium decay (the half-life of tritium is 12 years) and some evaporation.
- The development of equipment and techniques to flush and contain the tritium-bearing moderator present on fuel and target housings during disassembly-basin discharge.
- The diversion of disassembly-basin purges from streams to seepage basins in P- and C-Areas in 1978, which allowed a longer holdup time for radioactive decay before migration to streams via groundwater.

In addition, total tritium releases were reduced by the shutdown of R-Reactor in June 1964 and of L-Reactor from February 1968 until October 1985.

D.5.2 EFFECTS OF ALTERNATIVE COOLING WATER SYSTEMS ON TRITIUM RELEASES

Source terms used to calculate the current cumulative impact from liquid releases to the Savannah River are presented in Table D-15. Changes in releases of tritium as a result of alternative cooling water systems are presented in Table D-16.

Table D-15. Tritium and other Radionuclide Releases Used for Calculating Changes in Release Rates (Ci/yr)^a

Nuclide	Beaver Dam Creek	Four Mile Creek	Indian Grave Branch/ Pen Branch	Total release ^b
H-3	2.80×10^{-3}	1.35×10^{-4}	1.18×10^{-4}	3.08×10^{-4}
Co-58,60	-	2.64×10^{-5}	2.94×10^{-4}	7.41×10^{-4}
Sr-89,90	1.42×10^{-2}	5.49×10^{-1}	1.32×10^{-3}	5.72×10^{-1}
Pu-239	3.25×10^{-4}	1.13×10^{-2}	7.86×10^{-5}	1.19×10^{-2}
U-235,238	-	-	-	6.23×10^{-2}

a. Values are 5-year averages, 1980 through 1984, provided by Du Pont.

b. Total releases also include Tims Branch/Upper Three Runs Creek; Par Pond/Lower Three Runs Creek, and Steel Creek.

Table D-16. Changes in Release of Tritium to Savannah River from K- and C-Reactors in First Year for Each Cooling Water Alternative^a

Alternative cooling water system	Reactor	Change in release (Ci)
Recirculating cooling towers	K	-425
Once-through cooling tower, ^b discharge to Indian Grave Branch	K	-50.0
Recirculating cooling towers	C	-425
Once-through cooling tower, ^b discharge to Four Mile Creek	C	-50.0

a. DOE, 1984b.

b. Either a mechanical or a natural-draft once-through cooling-tower that receives its water by pumping or gravity feed.

The release of tritium to the Savannah River for the K- and C-Reactor once-through cooling-tower alternatives (pumped or gravity feed and mechanical or natural draft) is expected to be reduced by about 50 curies per year because of increased evaporation and a corresponding increase in the tritium released to the atmosphere. Similarly, the tritium released to the Savannah River from the K- and C-Reactor recirculating cooling-tower alternatives would also be reduced by about 425 curies and a correspondingly greater increase in the

tritium released to the atmosphere. The difference between the release rates of the recirculating cooling towers and once-through cooling tower is based on the differences in cooling-tower evaporation and blowdown rates.

D.5.3 OTHER RADIONUCLIDE RELEASES TO ONSITE STREAMS

Source terms for other radionuclides are presented in Table D-15.

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APPENDIX E

ARCHAEOLOGICAL AND HISTORIC RESOURCES

In accordance with the National Environmental Policy Act of 1969, Executive Order 11593, the National Historic Preservation Act of 1966 (as amended in 1986), and the Archaeological and Historic Preservation Act of 1974, archaeological and historic surveys were conducted for the analysis of the environmental consequences of the cooling water alternatives proposed for K- and C-Reactors and the D-Area powerhouse. These surveys focused on the watersheds of Pen Branch, Four Mile Creek, and Beaver Dam Creek, into which cooling water is discharged from these facilities.

This appendix describes the results of these surveys. In addition, it contains a list of sites in the six-county area near the Savannah River Plant (SRP) that are included in the National Register of Historic Places.

E.1 PEN BRANCH AND FOUR MILE CREEK ARCHAEOLOGICAL AND HISTORIC RESOURCES

An intensive archaeological survey of the Pen Branch and Four Mile Creek areas was conducted by the Savannah River Plant Archaeological Research Program, South Carolina Institute of Archaeology and Anthropology, from May 16 through August 17, 1984, at the request of the DOE Savannah River Operations Office (Martin, Hanson, and Brooks, 1984). At the time the survey was performed, cooling lakes were among the potential cooling water alternatives under consideration. Consequently, the survey focused on the proposed impoundment areas. Additionally, the areas that might be disturbed by the alternatives addressed in this environmental impact statement were encompassed by the survey. Table E-1 lists the sites included in this survey.

The survey located 65 discrete archaeological resources in the Pen Branch and Four Mile Creek watersheds. Analysis of the data recovered during the survey revealed human occupation from the Early Archaic through the Mississippian Period and from the 1780s through the 1950s. Table E-1 lists each of the sites by identification number, and presents information regarding periods of site occupation, site type, National Register eligibility, and recommended future activities at the site. Figure E-1 shows the location of these sites.

The sites located during the survey were divided into three groups to evaluate nomination eligibility for the National Register (36 CFR 63.3). The groups are (1) those sites that are not significant, (2) those that are potentially significant, and (3) those that are significant. Sites characterized as significant have sufficient content, integrity, and scientific importance to warrant their eligibility for the National Register. These sites would suffer adverse effects from any human activity that altered or destroyed the immediate environment.

Of the 65 sites, 42 are considered not significant because of low site integrity and the limited research potential. Factors contributing to the

Table E-1. Archaeological Resource Summary for Sites Recovered
During Survey of Pen Branch and Four Mile Creek

Site	Period of occupation ^a	Type of site ^b	Eligible for nomination to <u>National</u> <u>Register</u>	Recommended site preservation plan if ground disturbance occurs
38BR54	19th century	Prehistoric: habitation Historic: scatter	No	None
38BR58/59	2,4,5,6	Habitation	No	None
38BR62	1,2,5,6	Habitation	No	None
38BR63	4,5	Intrusive	No	None
38BR65	(?)	Intrusive	No	None
38BR71	1,2	Habitation	Yes	Data recovery: sample excavations; intensive excava- tions
38BR76	4,5	Limited activity	No	None
38BR77	(?)	Habitation	No	None
38BR78	4	Limited activity	No	None
38BR96	(?)	Limited activity	No	None
38BR97	4,5,6	Habitation	Yes	Data recovery: sample excavations; intensive excava- tions
38BR98	4	Limited activity	Yes	Data recovery: sample excavations; intensive excava- tions
38BR99	(?)	Limited activity	No	None

Table E-1. Archaeological Resource Summary for Sites Recovered
During Survey of Pen Branch and Four Mile Creek
(continued)

Site	Period of occupation ^a	Type of site ^b	Eligible for nomination to <u>National Register</u>	Recommended site preservation plan if ground disturbance occurs
38BR100	(?)	Limited activity	No	None
38BR280	8 (1880-1950)	Historic: dwelling	Yes	Data recovery: documentary search; intensive excavations
38BR282	8 (1880-1950) 4,5	Historic: dwelling Prehistoric: habitation	Yes	Data recovery: documentary search; sample excavations; intensive excavations
38BR289	8 (19th-20th century)	Mill dam	Yes	Data recovery: documentary search
38BR292	8 (19th-20th century)	Mill dam	Yes	Data recovery: documentary search
38BR297	3,4,5,6	Limited activity	Yes	Data recovery: sample excavations; intensive excavations
38BR298	(?)	Limited activity	No	None
38BR299	2,3,4,5 6,7	Habitation	Yes	Data recovery: sample excavations; intensive excavations
38BR305	8 (19th-20th century)	Mill and dam	Yes	Data recovery: documentary search; intensive excavations
38BR310	4,5,8 (19th-20th century)	Prehistoric: limited activity Historic: dwelling	Yes	Data recovery: sample excavations; intensive excavations

Table E-1. Archaeological Resource Summary for Sites Recovered
During Survey of Pen Branch and Four Mile Creek
(continued)

Site	Period of occupation ^a	Type of site ^b	Eligible for nomination to <u>National</u> <u>Register</u>	Recommended site preservation plan if ground disturbance occurs
38BR316	(?)	Intrusive	No	None
38BR318	3,4,5,6	Habitation	Yes	Data recovery: sample excavations; intensive excavations
38BR319	(?)	Limited activity	No	None
38BR322	(?)	Limited activity	No	None
38BR323	(?)	Limited activity	No	None
38BR335	(?)	Limited activity	No	None
38BR339	(?)	Intrusive	No	None
38BR345	4,5,6	Limited activity	No	None
38BR352	(?)	Limited activity	Yes	Data recovery: sample excavations; intensive excavations
38BR353	(?)	Limited activity	No	None
38BR355	3,4,5,6	Habitation	No	None
38BR357	1,2,3	Limited activity	No	None
38BR530	(?)	Limited activity	No	None
38BR531	2,3,4,5,6	Habitation	Yes	Data recovery: intensive excavations

Table E-1. Archaeological Resource Summary for Sites Recovered
During Survey of Pen Branch and Four Mile Creek
(continued)

Site	Period of occupation ^a	Type of site ^b	Eligible for nomination to <u>National Register</u>	Recommended site preservation plan if ground disturbance occurs
38BR532	4	Limited activity	Yes	Data recovery: sample excavations; intensive excavations
38BR533	(?)	Limited activity	No	None
38BR534	(?)	Limited activity	No	None
38BR535	4,5,6	Habitation	Yes	Data recovery: intensive excavations
38BR536	(?)	Limited activity	No	None
38BR537	6	Limited activity	No	None
38BR538	4,5	Limited activity	No	None
38BR539	4,5,6	Habitation	Yes	Data recovery: sample excavations; intensive excavations
38BR540	3,4,5,6	Habitation	Yes	Data recovery: intensive excavations
38BR541	1,4,6	Habitation	Yes	Data recovery: sample excavations; intensive excavations
38BR542	3,4,5,6	Habitation	Yes	Data recovery: intensive excavations
38BR543	(?)	Limited activity	No	None

Table E-1. Archaeological Resource Summary for Sites Recovered
During Survey of Pen Branch and Four Mile Creek
(continued)

Site	Period of occupation ^a	Type of site ^b	Eligible for nomination to <u>National Register</u>	Recommended site preservation plan if ground disturbance occurs
38BR544	(?)	Limited activity	No	None
38BR545	4,5,6	Habitation	Yes	Data recovery: sample excavations; intensive excavations
38BR547	(?)	Limited activity	No	None
38BR548	(?)	Limited activity	No	None
38BR549	(?)	Limited activity	No	None
38BR550	5	Limited activity	No	None
38BR551	8 (20th century)	Historic dump	No	None
38BR552	5,6	Limited activity	No	None
38BR555	4,5,6	Limited activity	No	None
38AK148	5,6	Limited activity	No	None
38AK149	4,5,6	Limited activity	No	None
38AK163	2,5	Limited activity	No	None
38AK414	(?)	Limited activity	No	None

Table E-1. Archaeological Resource Summary for Sites Recovered
During Survey of Pen Branch and Four Mile Creek
(continued)

Site	Period of occupation ^a	Type of site ^b	Eligible for nomination to <u>National Register</u>	Recommended site preservation plan if ground disturbance occurs
38AK415	5	Limited activity	No	None
38AK417	4,5,6	Habitation	Yes	Data recovery: sample excavations; intensive excavations
38AK418	5	Limited activity	Yes	Data recovery: sample excavations; intensive excavations

- a. 1 = Early Archaic Period (9500-7500 B.C.)
 2 = Middle Archaic Period (7500-3000 B.C.)
 3 = Late Archaic Period (3000-1000 B.C.)
 4 = Early Woodland Period (1000 B.C.-A.D. 1)
 5 = Middle Woodland Period (A.D. 1-700)
 6 = Late Woodland Period (A.D. 700-1000)
 7 = Mississippian Period (A.D. 1000-1700)
 8 = Historic Period (A.D. 1700-Present)
 ? = prehistoric lithic or ceramic debris--no specific time period
- b. Determined by the type and function of the artifact assemblage present at a site and its strategic location. A habitation site is defined as a base camp or area of long-term use where artifacts would be curated and manufactured and not necessarily taken along during food forays. Limited activity sites are defined as temporary, specialized, extractive sites (utilizing a specific local resource) with scarcity and lack of diversity within the artifact assemblage. Intrusive sites are those where artifacts located in the locale are the result of soil borrowing from another unknown area for pre-SRP construction activities. A historic dwelling is defined as the structural remains of a 19th-20th century building.

problem of low site integrity, include pre-1950s agricultural practices, pre-SRP construction activities, road construction and maintenance, and pine-plantation management practices.

Site 38BR548 is the only site that is potentially affected by the construction of cooling towers. It is one of the 42 sites. Site 38BR548 is a small, prehistoric lithic and ceramic scatter located on a terrace edge adjacent to the bank of the northern branch of Four Mile Creek. Sixteen systematic shovel tests were conducted at this site. Further research is not recommended for

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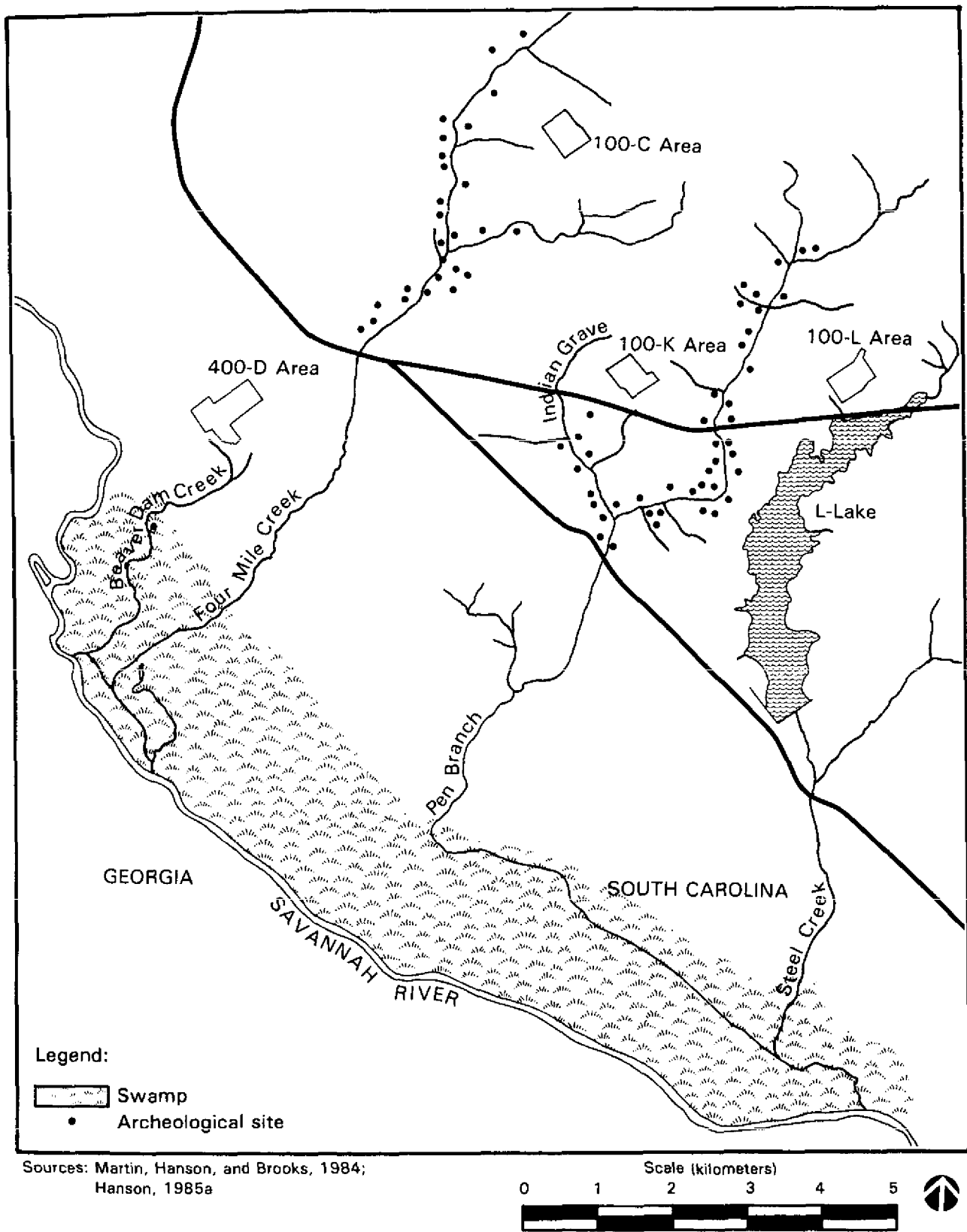


Figure E-1. General Map of the Survey Area Indicating Site Location

this site because the potential yield of additional information is negligible. A concurrence with the determination of "no effect," based on the absence of significant archaeological resources in the prepared construction areas, was issued by the State Historic Preservation Officer (Lee, 1986).

AT-1
AT-2
AZ-1

E.2 BEAVER DAM CREEK ARCHAEOLOGICAL AND HISTORIC RESOURCES

During October and November of 1985, an intensive archaeological survey was conducted along Beaver Dam Creek and in an area west of the creek near D-Area. The survey purpose was to locate and evaluate any archaeological resources that could be affected by implementation of cooling water alternatives in the D-Area, such as increased flow with mixing or direct discharge to the Savannah River via pipeline (Hansen, 1985a).

Shovel testing was conducted along the stream near the edge of the terrace because this area may be disturbed by increases in water flow in the creek. Testing revealed site 38BR450 along the stream. Site 38BR450, known as the Pie Site, is a large, multicomponent, prehistoric base camp/village at the junction of Beaver Dam Creek and the Savannah River swamp (Figure E-1). Originally recorded in 1982 as part of the general survey of the Savannah River Plant, this site has been tested extensively to determine its extent, depth, and composition. The site has a high level of archaeological integrity and significance for addressing contemporary research problems in the region.

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Based on these findings, site 38BR450 has been recommended for nomination eligibility to the National Register of Historic Places. Field examination of the site with respect to its proximity to the creek and the possible increase in water flow of 10 centimeters above normal levels indicates that no inundation of the location will occur. The site is buffered by a dense growth of natural vegetation which serves to protect it from the projected minor flow changes. The implementation of cooling water alternatives in D-Area would result in neither erosive action nor inundation of the prehistoric property. Concurrent with the request for determination of National Register eligibility for the site, a request for a determination of "no effect" was submitted to, then issued by the State Historic Preservation Officer (Lee, 1986 and Klima, 1986).

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AT-1
AT-2
AZ-1

A field survey was conducted in the area west of Beaver Dam Creek that may be disturbed by pipeline construction activities associated with the direct-discharge alternative for D-Area. The survey documented that the area had been extensively disturbed during initial SRP construction in the early 1950s, and no further evidence of intact archaeological resources was found. A review of the National Register of Historic Places also indicated that no sites are located in the area west of Beaver Dam Creek (Hansen, 1985b).

E.3 REGIONAL ARCHAEOLOGICAL AND HISTORIC RESOURCES

In 1986, 69 sites in the six-county area near SRP had been listed in the National Register (Table E-2). Richmond County, Georgia, has the largest number of sites (27), most being in and around the City of Augusta. Aiken County, South Carolina, has 18 sites.

TC

Table E-2. National Register Sites in the Six-County Area
Near the Savannah River Plant^a

Name	Location
AIKEN COUNTY, SOUTH CAROLINA	
Chancellor James Carrol House	Aiken
Coker Springs	Aiken
Legare-Morgan House	Aiken
Phelps House	Aiken
Dawson-Vanderhorst House	Northeast of Aiken
Fort Moore-Savano Town site	Beech Island vicinity
Redcliffe	Northeast of Beech Island
Graniteville Historic District	Graniteville
Silver Bluff	West of Jackson
Charles Hammond House	North Augusta
Rosemary Hall	North Augusta
Joye Cottage	Aiken
Chinaberry (Williams-Converse House)	Aiken
St. Mary Help of Christians Church	Aiken
Willcox's	Aiken
Pickens House	Aiken
Georgia Avenue-Butler Avenue Historic District	North Augusta
White Hall (Aiken Winter Colony)	Aiken
ALLENDALE COUNTY, SOUTH CAROLINA	
Antioch Christian Church	Southwest of Allendale
Erwin House	Southwest of Allendale
Gravel Hill Plantation	Southwest of Allendale
Red Bluff Flint Quarries	Allendale vicinity
Roselawn	Southwest of Allendale
Smyrna Baptist Church	South of Allendale
Lawton Mounds	Johnsons Landing vicinity
Fennell Hill	Peebles vicinity
Virginia Durant Young House	Fairfax
BAMBERG COUNTY, SOUTH CAROLINA	
General Francis Marion Bamberg House	Bamberg
Woodlands	Southeast of Bamberg
Rivers Bridge State Park	Ehrhardt vicinity
Voorhees College Historic District	Denmark vicinity
Bamberg Historic District	Bamberg
Cal Smoak Site	8 miles east of Bamberg

Table E-2. National Register Sites in the Six-County Area
Near the Savannah River Plant^a (continued)

Name	Location
BARNWELL COUNTY, SOUTH CAROLINA	
Banksia Hall	Barnwell
Church of the Holy Apostles	Barnwell
Church of the Holy Apostles Rectory	Barnwell
Old Presbyterian Church	Barnwell
Bethlehem Baptist Church	Barnwell
COLUMBIA COUNTY, GEORGIA	
Kiokee Baptist Church	Appling
Stallings Island	Northwest of Augusta
Woodville	Winfield vicinity
Columbia County Courthouse	Appling
RICHMOND COUNTY, GEORGIA	
Academy of Richmond County	Augusta
Augusta Canal Industrial Historic District	Augusta
Augusta Cotton Exchange	Augusta
Stephen Vincent Benet House	Augusta
Brahe House	Augusta
First Baptist Church of Augusta	Augusta
Fitzsimons-Hampton House	Augusta
Gertrude Herbert Art Institute	Augusta
Harris-Pearson-Walker House	Augusta
Meadow Garden	Augusta
Old Medical College Building	Augusta
Old Richmond County Courthouse	Augusta
Sacred Heart Catholic Church	Augusta
St. Paul's Episcopal Church	Augusta
Augusta National Golf Club	Augusta
Gould-Weed House	Augusta
Laney-Walker Historic District	Augusta
Lamar Building	Augusta
Reid-Jones-Carpenter House	Augusta
Woodrow Wilson Boyhood Home	Augusta
College Hill	Augusta vicinity
Broad Street Historic District	Augusta
Pinched Gut Historic District	Augusta
Summerville Historic District	Augusta
Greene Street Historic District	Augusta
Springfield Baptist Church	Augusta
Meadow Garden-George Walton House	Augusta

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AT-1
AT-2
AZ-1

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APPENDIX F

FLOODPLAIN/WETLANDS ASSESSMENT

F.1 INTRODUCTION

Executive Orders 11988 (Floodplains Management) and 11990 (Protection of Wetlands) and U.S. Department of Energy (DOE) regulation "Compliance with Floodplain/Wetlands Environmental Review Requirements" (10 CFR 1022) specify the requirements for a floodplain/wetlands assessment. Pursuant to these requirements, DOE issued a floodplain/wetlands notice on the construction and operation of alternative cooling water systems for the K- and C-Reactors and the D-Area coal-fired powerhouse on March 28, 1986 (51 FR 10654).

BC-19

The proposed action and cooling water alternatives discussed in this EIS, except the D-Area direct discharge alternative, do not occur within the base floodplain or wetlands. Consequently, the practicability test for identifying and evaluating alternatives outside the base floodplain is not required except the D-Area direct discharge alternative which is discussed in Section F.4.2. However, the implementation of the cooling water alternatives for K- and C-Reactors and the D-Area powerhouse could potentially impact the base floodplain and wetlands. These impacts are identified and assessed in Chapter 4. The impact identification and assessment requirements for the EIS are applicable and equivalent to the requirements for floodplain/wetlands protection.

This appendix references the EIS wherever possible and addresses only those impacts of the alternative cooling water systems that could affect the base floodplain and wetlands.

One of the primary concerns of the floodplain/wetlands Executive Orders is the protection of lives and properties. Access to the Savannah River Plant (SRP) is strictly controlled. No dwellings, hospitals, schools, nursing homes, or other structures are located within the base floodplain. Therefore, neither individuals nor private property would be affected if the cooling water alternatives were implemented.

Another concern in the floodplain/wetlands Executive Orders is the impact on floodplain values. The cooling water alternatives would have little or no impact on cultural resources, agricultural, aquacultural, or forestry resources as related to floodplain values. Archaeological and historic resource surveys, which are discussed in Appendix E, identified no significant sites requiring impact mitigation. Because of the controlled access to SRP, no agricultural or aquacultural practices exist, and none would be affected by implementation of any of the cooling water alternatives. The implementation of any of the alternatives, except the no-action alternative for K- and C-Reactors, would enhance native plant communities.

BC-19

The cooling water alternatives will, however, impact water and biological resources. This appendix discusses positive and negative, direct (concentrated) and indirect (dispersed), and short-term and long-term impacts associated with the construction and operation of the alternatives for each of the floodplain/wetland areas as related to both water and biological resources.

BC-23 | Short-term impacts are temporary changes during and immediately following implementation of an alternative. Impacts related to construction activities such as site clearing and sedimentation runoff are examples of short-term impacts. Long-term impacts can persist for a considerable time, and might continue indefinitely. Loss of mature swamp forest trees because of thermal effluents discharge is an example of a long-term impact. Direct impacts, as used in this EIS, are concentrated at or near the site of the action; indirect impacts occur at a site remote from the action. Impacts can be beneficial (i.e., positive) or harmful (i.e., negative). The alternative cooling water systems for K- and C-Reactors include the construction and operation of once-through cooling towers (gravity feed and natural draft), recirculating cooling towers, and the continuation of direct discharge, or no action. The alternatives considered for the D-Area coal-fired powerhouse include increased flow with mixing, direct discharge to the Savannah River, and continuation of the present operation, or no action. The proposed action and alternatives are discussed in Chapter 2.

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F.2 PEN BRANCH (K-REACTOR)

F.2.1 ONCE-THROUGH COOLING TOWER (PREFERRED ALTERNATIVE)

F.2.1.1 Construction Impacts

Water Resources

BC-19 | The principal direct impact to water resources in the Pen Branch floodplain/wetlands during construction would be on water quality. A negative impact of construction activities would be a temporary increase in suspended solids because of runoff erosion. Temporary measures such as berms, drainage ditches, drains, sedimentation basins, grassing, and mulching would control runoff until permanent erosion-control measures could be implemented. Construction activities would have no measurable effect on groundwater recharge or the ability of the floodplain/wetlands to moderate floods. Water quality impacts are discussed in Chapter 4.

TE |

Biological Resources

TE | Construction activities would occur on upland sites and would not directly affect the floodplain/wetlands. The principal indirect impact would be from sediment loading on fish and macroinvertebrates. This short-term impact would be minimal because Pen Branch, in the vicinity of the proposed construction, is uninhabitable by aquatic and semiaquatic biota because of the high water temperatures from reactor operations.

F.2.1.2 Operational Impacts

Water Resources

BC-4 | The principal direct impact to water resources in Pen Branch floodplain/wetlands during operation would be on water quality. A positive impact would be that water temperatures at the outfall would be reduced from a maximum of 75°C to 30°C in the summer, only 3°C above projected ambient temperatures. In the winter, the discharge temperature would decrease even

more to approximately 26°C (12°C above ambient creek temperature). Lower water temperatures would improve water quality by increasing the dissolved oxygen concentration.

Operation of the once-through cooling tower would reduce both suspended solids and the sedimentation rates of the delta, a positive impact. Some erosion and sedimentation would occur. However, the sedimentation rates of the delta should decrease as plant growth becomes reestablished along the stream banks. This would be a positive impact because of the prevention of further vegetative loss caused by thermal effluents. Operations would have no measurable impact on the ability of the floodplain/wetlands to moderate floods or groundwater recharge. Stream flow would be reduced slightly from 11.3 to about 10.5 cubic meters per second, and should cause a slight reduction in suspended solids concentrations, a positive impact. Water quality and hydrology impacts are discussed in Chapter 4.

BC-10
BC-19

Biological Resources

The most significant positive ecological impact would be the enhancement of wetland habitat because of diminished thermal effects of the discharges. Vegetation would become reestablished on portions of the 670 acres of affected wetlands. The vegetation loss rate in the swamp of 26 acres per year because of thermal impacts would be reduced (see Chapter 4). The reduction in stream flow could contribute to a slight reduction in canopy loss from flooding and increased sedimentation, another positive impact.

BC-19

Implementation of this alternative should enhance the diversity of plant and animal life over present conditions, a positive impact. Spawning conditions for indigenous and migratory fish species would be greatly improved. Operation of the cooling tower would meet the requirements stipulated for Maximum Weekly Average Temperature (MWAT) for fish survival during a winter shutdown (EPA, 1977; Muhlbaier, 1986); this would be a positive impact.

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Two species at SRP would be affected positively by this alternative. Because the water temperature would be well below the thermal maximum temperature tolerance of the threatened American alligator (Alligator mississippiensis; classified as "threatened due to similarity of appearance"), additional habitat for it and other aquatic species would be created.

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Reducing the temperature below the thermal maximum for fish would allow fish to recolonize Pen Branch, a positive impact. The fluctuating water levels could concentrate fish, the principal prey of the endangered wood stork (Mycteria americana). This would be a positive impact because loss of foraging habitat has contributed to the decline of the wood stork (Du Pont, 1985).

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Based on formal consultation between the U.S. Fish and Wildlife Service (FWS) and DOE on the American alligator, red-cockaded woodpecker, and wood stork, FWS has issued a biological opinion of "no effect" if DOE implements the preferred alternatives (Parker, 1986).

TC

Because this alternative would not require any changes in the cooling water intake structures or flow rates, there would be no change in the entrainment or impingement impacts. Consultation between DOE and the National Marine

TE Fisheries Service has determined that SRP operations would have no adverse impacts on the endangered shortnose sturgeon, Acipenser brevirostrum (Oravetz, 1983). Biological impacts are discussed in Chapter 4.

TE Vegetation near the cooling tower would be subject to salt deposition attributable to drift from the tower. Cooling tower drift could cause vegetation stress, either directly by deposition of salts on the foliage or indirectly from excess accumulations of salts in the soil. Salt stress in plants could occur through various mechanisms. This stress includes: (1) increased osmotic potential of the soil solution affecting the availability of soil moisture to the plant; (2) alteration of the mineral nutrition balance in the salt tissue; and/or (3) toxic effects due to specific ion concentrations in the plants (Bernstein, 1975; Hanes, Zelazny, and Blaser, 1970; Allison, 1964; Levitt, 1980).

TE Tolerances and susceptibility to salt deposition are highly variable, depending on the plant species and other conditions in the environment. Vegetative studies indicated that thresholds for development of visible salt stress symptoms on the most sensitive species were approximately 83 kilograms (183 pounds) per acre per year of sodium chloride salt (INTERA, 1980). Studies indicate that at sodium chloride deposition rates of about 41 kilograms (90 pounds) per acre per year, agricultural productivity can be reduced (Mulchi and Armbruster, 1981).

TE The drift composition is equivalent to that of the circulating water. The concentration of substances in the circulating water for this alternative is shown in Table 3-3. The substance of particular interest with regard to its potential for damage is the chloride ion. The other constituents in the table are at low concentrations and considered negligible or are potentially beneficial.

TC The implementation of this alternative would result in an estimated total solids deposition of 0.5 kilogram (1.1 pounds) per acre per year within 2 kilometers of the cooling tower. The sodium chloride deposition rates from the cooling tower are much less than the critical values reported by Mulchi and Armbruster (1981), INTERA (1980), and NRC (1979) that can cause reduced productivity of plant species. Therefore, no significant impacts on vegetation are expected with this alternative.

F.2.2 RECIRCULATING COOLING TOWERS

F.2.2.1 Construction Impacts

Water Resources

BC The principal impacts to water resources in the Pen Branch floodplain/wetlands during construction would be similar to those for described the once-through cooling-tower alternative in Section F.2.1.1. Suspended solids because of runoff erosion should be slightly lower, and a projected 50 acres of upland habitat would be disturbed versus 25 acres for the once-through cooling-tower alternative during construction activities.

Biological Resources

Biological resource impacts would be similar to those associated with the construction of the once-through cooling tower (see Section F.2.1.1).

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F.2.2.2 Operational Impacts

Water Resources

Implementation of this alternative would primarily affect water quality. As with the once-through cooling tower alternative, effluent temperatures would closely duplicate ambient temperatures, a positive impact. Under winter conditions, the average discharge temperature would be about 15°C, about 5°C to 7°C above the ambient stream temperature. Dissolved oxygen levels would improve if this alternative were implemented and would comply with State Class B water classification standards throughout the year, a positive impact. Nutrient concentrations would increase at the tower outfall under this alternative, but total loading (quantity) of nutrients and other chemicals transported to the swamp/river system would not increase.

BC-14

Water consumption from the Savannah River would be reduced from about 11.3 cubic meters per second to about 1.7 cubic meters per second, a positive impact.

The implementation of this action would result in greater reductions in suspended solids and the sedimentation rates of the delta than the once-through alternative. The most significant reduction in sedimentation and delta growth rate impacts would be from the reduction in stream flow rates, a positive impact. Under this alternative, discharge flows would decrease from 11.3 cubic meters per second to about 0.6 cubic meter per second, and stream channel depth and width would be reduced substantially. Operations would have no measurable impact on the ability of the floodplain/wetlands to moderate floods or groundwater recharge.

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Biological Impacts

The most significant ecological impact would be the enhancement of wetland habitat because of the reduced flow and thermal effects, a positive impact. Vegetation would become reestablished on about 500 acres of the thermally impacted 670 acres of wetlands and the vegetation loss rate associated with the delta growth (26 acres per year, average 1974-1984) would be substantially reduced.

BC-19

Stream flows and temperatures would more closely follow ambient conditions and would facilitate plant and animal diversity over present conditions, a positive impact. Spawning conditions for indigenous and migratory fish species would be greatly improved. With discharge temperatures similar to ambient temperature, there would be no potential for cold shock during a winter reactor shutdown. Changes in flow volumes, when they occur, would be smaller than with other alternatives and would tend to minimize changes in stream morphology. This should stabilize aquatic and wetland habitats.

Two species at SRP would be affected by this alternative. The impact on the American alligator which is classified as "threatened due to similarity of

appearance" should be positive (i.e., increased habitat). The decrease in water flow would allow vegetation to become reestablished over a larger area than the once-through alternative.

Fish and other vertebrates would be able to inhabit the stream channel, providing potential foraging habitat for the endangered wood stork. Fluctuations in water levels would decrease compared to those from the once-through alternative. Consequently, the potential for fish populations becoming concentrated in small pools, providing foraging habitat for the wood stork, would decrease.

Through natural vegetative succession, a large area of the impacted floodplain/wetlands should eventually return to a closed-canopy forest, thereby providing food and cover for numerous species of wildlife.

Because the rate of entrainment for fish eggs and larvae is directly proportional to the water intake flow rate, entrainment losses would be proportionally reduced (approximately 85 percent). Estimated impingement losses would also be reduced by a similar amount. Biological impacts are discussed in Chapter 4.

TC Implementation of this alternative would result in an estimated total solids deposition of about 22.7 kilograms (50 pounds) per acre per year within 0.5 kilometers. At 2 kilometers, the predicted solids deposition is calculated to be about 2.2 kilograms (5.0 pounds) per acre per year. Because the deposition rates at 2 kilometers are much less than the critical values reported (see Chapter 4), no significant impacts on vegetation are expected at or beyond this distance with this alternative.

F.2.3 NO ACTION - EXISTING SYSTEM

F.2.3.1 Operational Impacts

Water Resources

The impacts on water resources of the No-Action alternative are mostly negative. The annual average flow in Pen Branch below the K-Reactor cooling water discharge point would continue to be about 11.8 cubic meters per second, 11.3 cubic meters per second above natural stream flow. The thermal maximum temperature tolerance for most aquatic and terrestrial species would continue to be exceeded. The dissolved oxygen levels would continue to fall below minimum South Carolina water classification standards during the summer. Suspended solids and sedimentation rates for delta expansion would continue. Stream morphology has been permanently altered because of approximately 30 years of discharge at 11.3 cubic meters per second. Because of this alteration, continued operations would have little impact on the ability of the Pen Branch floodplain/wetlands to moderate floods. Continued operations would have little impact on the ability of the swamp floodplain/wetlands adjacent to Pen Branch to moderate floods because this is controlled by the Savannah River (483 cubic meters per second of flow during flood stage). Groundwater recharge in this area is primarily controlled by the Savannah River. Water quality and hydrology impacts are discussed in Chapter 4.

Biological Resources

The impacts on biological resources of the no-action alternative are negative. The flora along the creek would continue to be sparse, reflecting the harsh temperature regime. Most aquatic invertebrates would remain absent from the creek. Fish would not be able to inhabit the creek where their thermal maximum temperature tolerance is exceeded, and the fish fauna above the thermal discharge point would continue to be depauperate in number and diversity. Limited use by threatened and endangered species in Pen Branch would continue under existing conditions. Entrainment and impingement rates would remain at the present level. Biological impacts are discussed in more detail in Chapter 4.

F.3 FOUR MILE CREEK (C-REACTOR)

F.3.1 ONCE-THROUGH COOLING TOWER (PREFERRED ALTERNATIVE)

F.3.1.1 Construction Impacts

Water Resources

The types of construction impacts of the once-through cooling tower for C-Reactor on water resources and biological resources in Four Mile Creek would be similar to those described for K-Reactor on Pen Branch (see Section F.2.1.1 and Chapter 4).

F.3.1.2 Operational Impacts

Water Resources

The operational impacts of the once-through cooling tower for C-Reactor on water resources would be similar to those described for K-Reactor on Pen Branch (see Section F.2.1.2 and Chapter 4).

The cooling effect would be the same as that projected for Pen Branch in that temperatures would meet the 32.2°C Class B water classification standard, but would be 10°C to 13°C above ambient creek temperature at the point of discharge during the winter.

BC-14

Biological Resources

Operational impacts of the once-through cooling tower for C-Reactor on biological resources would be similar to those described for K-Reactor (see Section F.2.1.2 and Chapter 4). Vegetation would become reestablished on portions of the 1147 acres of affected wetlands, and the vegetation loss rate in the swamp of 28 acres per year due to thermal impacts would be reduced, a positive impact. The implementation of this alternative would further enhance foraging habitat for wood storks, a positive impact. The cooling tower would be designed and operated to meet the requirements stipulated for MWAT for fish survival during a winter shutdown (EPA, 1977; Muhlbaier, 1986); this would be a positive impact.

BC-19

Deposition of cooling tower drift would be similar to that projected for the once-through cooling tower alternative for K-Reactor [i.e., 0.5 kilogram (1.1 pounds) per acre per year within 2 kilometers]. Because these deposition rates are much less than the critical values (see Chapter 4), there would be no impacts on vegetation with this alternative.

F.3.2 RECIRCULATING COOLING TOWERS

F.3.2.1 Construction Impacts

Water Resources

BC-19 | The construction impacts of recirculating cooling towers for C-Reactor on water resources and biological resources would be similar to those described for K-Reactor on Pen Branch (see Section F.2.3.1). Sedimentation runoff impacts should be similar (short-term) because projected disturbances (60 acres) approximate those for the K-Reactor recirculating cooling tower (50 acres).

F.3.2.2 Operational Impacts

BC-19 | The operational impacts of recirculating cooling towers for C-Reactor on water resources and biological resources would be similar to those described for K-Reactor on Pen Branch (see Section F.2.2.2 and Chapter 4). It is estimated that approximately 1000 acres of the thermally impacted 1147 acres of wetland vegetation would become reestablished, a positive impact.

TC | The implementation of this alternative would result in an estimated total solids deposition of 2.2 kilograms (4.8 pounds) per acre per year within 2.0 kilometers of the cooling towers. Because this rate at 2 kilometers is much less than the critical threshold values reported that can cause reduced productivity of plant species (see Section F.2.1.2 and Chapter 4), no significant impacts on vegetation are expected with this alternative.

F.3.3 NO ACTION - EXISTING SYSTEM

F.3.3.1 Operational Impacts

The operational impacts of the no-action alternative on water resources and biological resources are similar to those described for K-Reactor on Pen Branch (see Section F.2.3 and Chapter 4).

F.4 BEAVER DAM CREEK (D-AREA POWERHOUSE)

F.4.1 INCREASED FLOW WITH MIXING (PREFERRED ALTERNATIVE)

F.4.1.1 Construction Impacts

Existing structures would be used for increasing flow. Consequently, there would be no construction or short-term impacts associated with this alternative.

F.4.1.2 Operational Impacts

Water Resources

Water quality monitoring studies have shown that temperature is the only Class B water classification standard not currently being met and that the thermal limits are exceeded only during the late spring and summer months (Du Pont, 1985). During summer extremes, discharges to the creek presently range from 32°C to 34°C. Implementation of this alternative would reduce these effluent temperatures sufficiently to meet State Class B water classification standards. Potential impacts that could occur include small increases in stream suspended solids caused by intermittently increased stream flow (i.e., increases in flow with average increments from 2.7 cubic meters per second to 4.0 cubic meters per second), depending on the number of additional pumps needed to meet temperature requirements (see Chapter 2). Operations under this alternative would have little impact on the ability of the floodplain/wetlands to moderate floods or groundwater recharge, because these activities are predominantly influenced by the Savannah River (Du Pont, 1985).

BC-14

BC-10

Biological Resources

Mean water temperatures at the mouth of Beaver Dam Creek would be about 4°C and 1°C above ambient creek temperatures in the spring and summer, respectively. Water temperatures would be about 7°C above ambient during the winter. Increased flow during the spring and summer months would increase aquatic habitat and should increase the abundance and diversity of fish and macroinvertebrates. However, wildlife habitat would be temporarily reduced during periods of increased pumping.

BC-14

The increased flow would cause temporary increases in stream channel erosion and would increase siltation. This increased siltation would generally occur after peak spawning in May and June. However, during some years increased flow could be required as early as May or June, a potentially negative impact. Any increase in vegetation loss due to delta growth should be minimal and offset by vegetation reestablishment and succession on previously impacted thermal areas. A reversal in the pattern of the canopy loss is already being observed. It is thought this pattern is because of a reduction in effluent temperatures that began in 1978 and has continued (Du Pont, 1985).

The alligator, which is classified as "threatened due to similarity of appearance," and the endangered wood stork could be affected by this alternative. The Beaver Dam Creek area supports a large population of alligators, and the mild thermal effluent during the winter probably enhances the survivability of juvenile alligators. Implementation of this alternative would have no impact on winter thermal effluent. Therefore, it should have no impact on winter alligator populations. Intermittently increased flows during the spring and summer would cause the water level in Beaver Dam Creek to alternately rise and fall 12 to 19 centimeters (see Chapter 4). Water-level increases less than or equal to 35 centimeters are not expected to affect alligator nesting sites (Specht, 1985).

TC

Wood storks frequently forage in the Beaver Dam Creek swamp, although feeding habitat is marginal quality when compared to other areas at SRP (Du Pont, 1985). An increase in water levels of 12 to 19 centimeters could be too deep

at times for foraging activities. Conversely, increased water levels could prevent or delay potential foraging areas from drying up during droughts because the Beaver Dam Creek foraging sites are not associated with the more permanent wetlands found along primary and secondary creeks.

BD-5

Entrainment losses would be approximately 2.0×10^6 fish eggs and larvae if this alternative were implemented. Entrainment of the eggs and larvae of the endangered shortnose sturgeon should not occur. This is due to the demersal and adhesive nature of their eggs, as well as to the time of year shortnose sturgeon spawn (February-March). Fish impingement on the 5G intake screens would increase by 113 fish per year or to 1831 total fish per year. Biological impacts are discussed in Chapter 4 and Appendix C.

F.4.2 DIRECT DISCHARGE TO SAVANNAH RIVER

F.4.2.1 Direct Impacts to Floodplains/Wetlands and Practicable Alternatives

Implementation of this alternative would temporarily disturb approximately 1 acre of floodplain/wetlands during construction. The overall operational impact would be to return Beaver Dam Creek to its approximate original status as an intermittent stream. Implementing this action would reduce floodplain/wetland values because current operations enhance certain wildlife values (see Section F.4.3.1 and Chapter 4).

An alternative action that would achieve the intended thermal performance standards but would minimize harm to or within the floodplain/wetlands is described in Section F.4.1; the no-action alternative is described in Section F.4.3. Because public access to and use of SRP are strictly controlled, no individual or private property would be affected by this alternative. In addition, no impact would directly or indirectly support floodplain development. Neither would there be an impact on cultural resources, agriculture, aquaculture, nor forestry resources as they relate to floodplain values.

F.4.2.2 Construction Impacts

Water Resources

The principal direct impact to water resources in the Beaver Dam Creek floodplain/wetlands during construction would be on water quality. A pipeline would be constructed parallel to the existing intake pipe. This pipeline would run from the D-Area powerhouse across the Beaver Dam Creek swamp to a discharge point on the Savannah River below the cooling water intake structure. The pipeline would cross approximately 1 acre of floodplain/wetlands. The construction activities would result in a temporary increase in turbidity and suspended solids. Construction impacts would have no measurable effect on groundwater recharge or on the ability of floodplain/wetlands to moderate floods.

Biological Resources

The principal indirect impact would be from sediment loading on fish and micro-invertebrates in Beaver Dam Creek. When construction activities cease, suspended solids levels should return quickly to ambient conditions. Wildlife

TE

might be disturbed by the noise associated with construction activities. This disturbance is short-term and noncumulative. TE

F.4.2.3 Operational Impacts

Water Resources

The principal direct impact to water resources in the Beaver Dam Creek floodplain/wetlands would be to the decrease in stream flow from the present average of 2.7 cubic meters per second to only 0.2 cubic meter per second. Beaver Dam Creek and the adjacent swamp would essentially return to their approximate original conditions, a wetland with an intermittent stream. Periodic flooding would depend entirely on natural flooding from the Savannah River and storm runoff after rains. Based on pump test data (Specht, 1985), any flooding of Beaver Dam Creek because of storm runoff would have a short duration. The water level in Beaver Dam Creek swamp would return to its original level approximately 24 hours after the rainfall stopped.

Biological Resources

The most significant ecological impact would be a loss of nesting and foraging habitat for wildlife. The implementation of this alternative would decrease or eliminate nesting habitat for the American alligator and any thermal refugia that might have existed during the winter months. Foraging habitat for the wood stork would be significantly decreased or eliminated. Beaver Dam Creek would return to its approximate original condition as an intermittent stream (Moyer, 1985), thus negatively impacting aquatic organisms.

Because the thermal effluent would be pumped directly to the Savannah River, there would be a small thermal plume at the outfall structure. Because of the small volume of mildly thermal effluent and the large volume of ambient river water, there would be no thermal impact outside the mixing zone. There would be a large zone of passage for all fish species, including the endangered shortnose sturgeon. There would be no impact on the shortnose sturgeon from entrainment and impingement with implementation of this alternative. TE

F.4.3 NO ACTION - EXISTING SYSTEM

F.4.3.1 Operational Impacts

Water Resources

The flow of 2.7 cubic meters per second would continue. Water temperatures in the creek and delta could reach 34°C under extreme summer conditions. Concentrations of dissolved oxygen would be somewhat lower than those in unimpacted streams. Continued operations would have no measurable impact on the ability of the floodplain wetlands to moderate floods or groundwater recharge. Water resource impacts are discussed in Chapter 4. BC-14

Biological Resources

The aquatic and terrestrial ecology of the creek would continue to be affected by the thermal effluent but to a much lesser extent than that of Pen Branch or

Four Mile Creek. Portions of Beaver Dam Creek would continue to show evidence of revegetation and succession due to a slight decline in water temperatures that began in the 1970s. The area around the creek would continue to provide habitat for a dense population of alligators and foraging habitat for the wood stork.

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APPENDIX G

RADIATION DOSE CALCULATION METHODS AND ASSUMPTIONS

The operation of alternative cooling water systems for the K- and C-Reactors at the Savannah River Plant (SRP) would change the amount of radioactive materials released to the environment. Cooling alternatives associated with the D-Area would not cause any changes in radioactive releases to the environment. This appendix describes the methods and assumptions used to (1) determine the change in radiological impacts expected to result from the operation of the cooling alternatives, and (2) determine the doses expected from the operation of facilities on or within 80 kilometers of SRP without the implementation of cooling alternatives (no action - existing conditions).

The cooling water alternatives for K- and C-Reactors that are considered in this EIS are existing operation (no action), recirculating cooling towers, and once-through cooling towers. For the once-through alternative, doses were analyzed for gravity-flow, natural-draft cooling towers without holding ponds. For the recirculating alternative, doses were analyzed for gravity-flow, natural-draft cooling towers pumped to mechanical-draft cooling towers without holding ponds.

The implementation of a once-through or recirculating cooling-tower alternative for K- and C-Reactors would change the amount of radionuclides released to the environment. Because of an increase in evaporation from cooling towers, a greater amount of tritium would be released to the atmosphere, resulting in a positive tritium source term. However, for liquid releases the tritium source term would decrease by the same amount and, therefore, would be considered a negative value. Also, the implementation of alternative cooling water systems might cause a change in the rate of remobilization of radionuclides present in creek beds. Remobilization is discussed in Section G.2 and Appendix D.

Radioactive materials released to the environment generally become involved in a complex series of physical, chemical, and biological processes. The principal pathways by which radioactivity released from a facility can reach people are (1) exposure to nuclides in the air, in the water, or on the ground, (2) inhalation of radioactivity, and (3) ingestion of radioactivity in food and water. Figure G-1 shows these pathways.

The calculations of radiological doses to members of the public from these various pathways are based on methods recommended by the U.S. Nuclear Regulatory Commission (NRC) for licensing power reactors. However, the dose-conversion factors were taken from ICRP Publication 30 (ICRP, 1979). Estimates of doses are based on detailed analyses of the sources and rates of radioactive releases and the pathways by which people can be exposed to dispersed radioactive materials. The NRC methods are adapted to specific SRP conditions.

In the calculation of doses, the dose-conversion factors for adults presented in ICRP-30 were used. Dose factors for other age groups have not yet been published by the ICRP. However, age-specific usage factors were used to

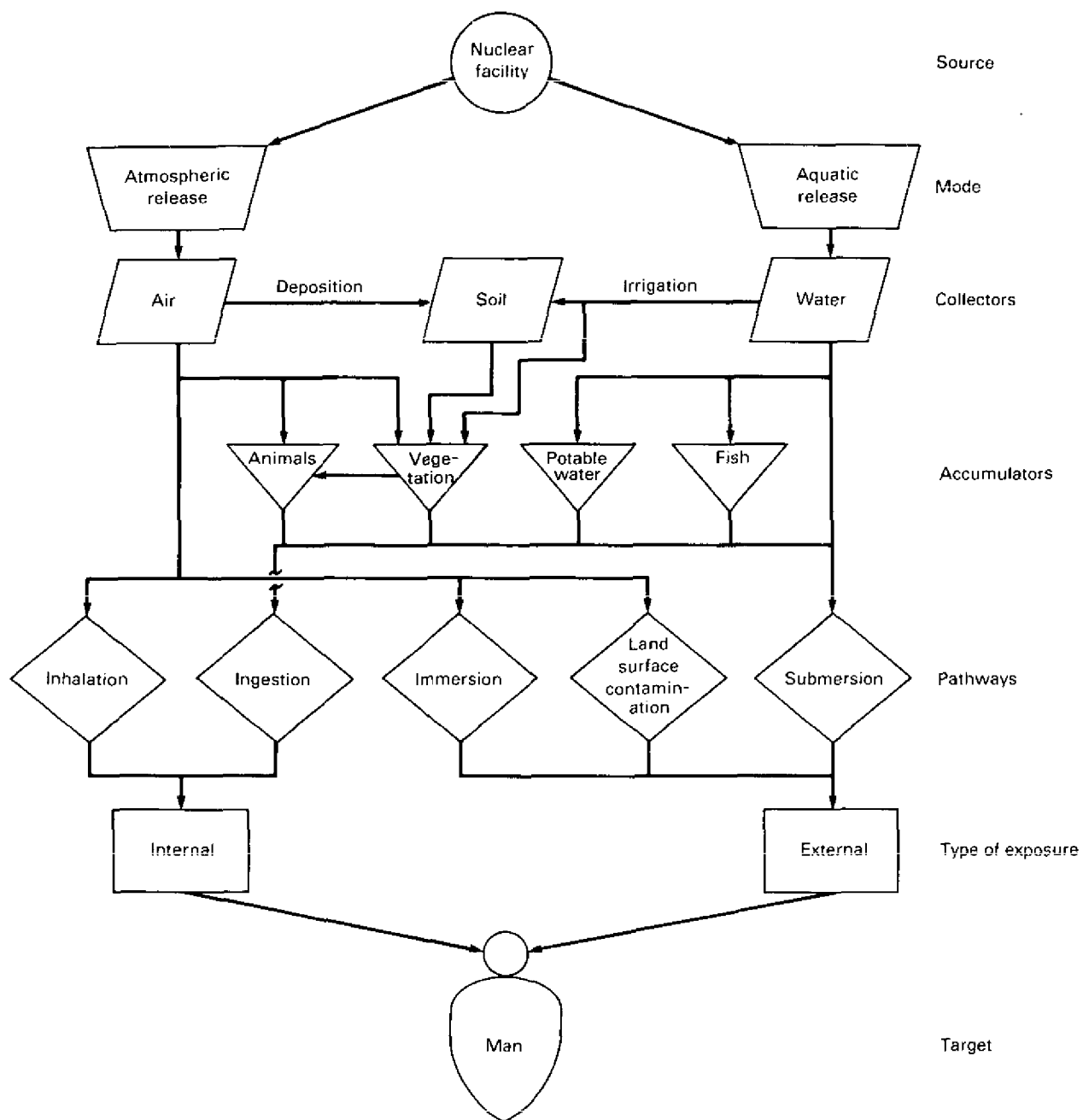


Figure G-1. Exposure Pathways Considered in Radiological Impact Assessments

calculate doses. The age groups considered were infant (0 to 1 year old), child (1 to 11 years old), teen (11-17 years old), and adult (17 years old and older).

Dose-conversion factors are provided in ICRP-30 for many organs. These factors depend on the physical and chemical nature of the radionuclide. The oral- and inhalation-dose conversion factors chosen for tritium presume it to be in the form of tritiated water. Also, to account for tritium absorption through the skin, the inhalation-dose conversion factor is increased by a factor of 0.5. For all radionuclides released to the environment, an effective-whole-body-dose conversion factor was obtained by multiplying the individual-organ-dose conversion factors by the health-risk weighting factors presented in ICRP-30 and summing the results.

Radiation doses are calculated for the maximally exposed individual. In addition, collective radiation doses are calculated for the population within 80 kilometers of the Savannah River Plant and that population served by the Beaufort-Jasper County and Cherokee Hill (Port Wentworth) water-treatment plants.

G.1 ATMOSPHERIC RELEASES

For airborne releases, annual average air concentration and ground deposition per unit release (X/Q and D/Q) were calculated for each of 160 segments (16 wind-direction sectors at 10 distances) within an 80-kilometer radius of the site and for the site boundaries, using the methods implemented in the NRC computer program XOQDOQ (Sagendorf and Goll, 1976). Site-specific meteorological data were used to generate joint-frequency distributions (JFDs) of wind speed, stability, and direction for input to XOQDOQ (Table G-1). These stability windrose statistics were derived by 1-hour averaging of data collected at the 61-meter level of the SRP H-Area meteorological tower during the 5-year period from 1975 to 1979. Stability class was determined from the observed azimuthal and vertical standard deviations (σ_θ and σ_ϕ). Values of X/Q and D/Q by compass sector and radial increment for ground-level and elevated releases (using the windspeed measured at a height of 61 meters) are presented in Tables G-2 and G-3, respectively. Flat terrain was assumed; no credit was taken for plume rise induced by momentum or thermal effects.

TC

The meteorological dispersion parameters obtained by running the XOQDOQ code are used as input to the NRC GASPAR code (Eckerman et al., 1980), which implements the radiological exposure models of Regulatory Guide 1.109, Revision 1 (NRC, 1977), to estimate doses from atmospheric exposure pathways to the effective whole body and various organs. Dose-conversion factors presented in ICRP-30 were input to the GASPAR code. Population distribution data and milk-, meat-, and vegetable-production distribution data (Table G-4) for the 16 wind-direction sectors are also used as input to GASPAR for calculating the collective dose to the regional population; the term "regional population" refers to those individuals residing within 80 kilometers of the Plant. Population data for the year 2000 are used in this analysis.

Source terms that are input to the GASPAR code and used in the calculation of doses to the maximally exposed individual and the regional population are

Table G-1. Joint-Frequency Distribution of Wind: H-Area Tower, 1975-1979

Wind speed class (m/sec)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
ATMOSPHERIC STABILITY CLASS A (VERY UNSTABLE)																	
0.0-2.0	0.39	0.32	0.39	0.33	0.32	0.38	0.41	0.40	0.37	0.36	0.40	0.40	0.56	0.61	0.46	0.39	6.49
2.1-4.0	0.31	0.28	0.31	0.42	0.59	0.64	0.68	0.48	0.48	0.45	0.49	0.44	0.56	0.63	0.53	0.34	7.62
4.1-6.0	0.04	0.05	0.05	0.08	0.18	0.15	0.08	0.08	0.09	0.13	0.17	0.12	0.09	0.09	0.14	0.08	1.64
6.1-8.0	0.01	0.00	0.01	0.01	0.03	0.01	0.01	0.00	0.06	0.06	0.01	0.02	0.03	0.02	0.03	0.01	0.31
8.1-12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.09
12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ATMOSPHERIC STABILITY CLASS B (UNSTABLE)																	
0.0-2.0	0.09	0.10	0.17	0.13	0.17	0.18	0.14	0.11	0.15	0.11	0.11	0.22	0.22	0.23	0.19	0.13	2.46
2.1-4.0	0.19	0.14	0.27	0.39	0.38	0.41	0.36	0.26	0.29	0.26	0.29	0.29	0.37	0.44	0.31	0.28	4.92
4.1-6.0	0.05	0.05	0.07	0.26	0.27	0.21	0.13	0.12	0.21	0.24	0.18	0.17	0.16	0.28	0.27	0.18	2.85
6.1-8.0	0.02	0.02	0.01	0.04	0.03	0.02	0.00	0.03	0.06	0.05	0.03	0.04	0.05	0.02	0.07	0.03	0.53
8.1-12.0	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.02	0.02	0.01	0.08
12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ATMOSPHERIC STABILITY CLASS C (SLIGHTLY UNSTABLE)																	
0.0-2.0	0.12	0.11	0.21	0.19	0.18	0.17	0.16	0.13	0.14	0.16	0.16	0.13	0.25	0.29	0.15	0.18	2.75
2.1-4.0	0.20	0.19	0.39	0.62	0.69	0.58	0.45	0.47	0.29	0.36	0.40	0.38	0.66	0.60	0.49	0.35	7.11
4.1-6.0	0.11	0.10	0.18	0.50	0.55	0.46	0.23	0.24	0.37	0.44	0.32	0.42	0.47	0.49	0.46	0.23	5.58
6.1-8.0	0.01	0.02	0.04	0.18	0.14	0.02	0.06	0.08	0.07	0.11	0.11	0.15	0.18	0.18	0.37	0.19	1.92
8.1-12.0	0.01	0.01	0.01	0.01	0.02	0.00	0.00	0.03	0.01	0.02	0.05	0.03	0.10	0.11	0.26	0.09	0.76
12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.02
ATMOSPHERIC STABILITY CLASS D (NEUTRAL)																	
0.0-2.0	0.11	0.10	0.17	0.18	0.17	0.14	0.18	0.18	0.17	0.17	0.16	0.23	0.31	0.32	0.22	0.15	2.98
2.1-4.0	0.31	0.34	0.58	0.79	1.02	0.98	0.66	0.70	0.51	0.49	0.82	0.68	0.79	0.88	0.77	0.54	10.87
4.1-6.0	0.16	0.16	0.33	0.82	0.78	0.68	0.57	0.62	0.62	0.93	0.73	0.73	0.83	1.14	1.22	0.41	10.73
6.1-8.0	0.06	0.04	0.06	0.15	0.08	0.06	0.12	0.17	0.20	0.23	0.23	0.27	0.36	0.50	0.83	0.21	3.56
8.1-12.0	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.02	0.04	0.05	0.08	0.08	0.24	0.37	0.47	0.15	1.53
12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.05	0.02	0.00	0.11

Table G-1. Joint-Frequency Distribution of Wind: H-Area Tower, 1975-1979 (continued)

Wind speed class (m/sec)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
ATMOSPHERIC STABILITY CLASS E (SLIGHTLY STABLE)																	
0.0-2.0	0.05	0.10	0.16	0.06	0.09	0.06	0.15	0.08	0.19	0.08	0.12	0.16	0.18	0.14	0.11	0.09	1.81
2.1-4.0	0.26	0.28	0.43	0.27	0.56	0.38	0.67	0.45	0.41	0.27	0.63	0.63	0.58	0.43	0.51	0.38	7.13
4.1-6.0	0.21	0.19	0.37	0.69	0.58	0.55	0.65	0.64	0.65	0.80	0.92	0.74	0.86	0.84	0.57	0.37	9.64
6.1-8.0	0.01	0.01	0.09	0.06	0.03	0.05	0.10	0.03	0.08	0.15	0.14	0.13	0.14	0.08	0.03	0.02	1.16
8.1-12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.03
12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ATMOSPHERIC STABILITY CLASS F (STABLE)																	
0.0-2.0	0.03	0.01	0.03	0.02	0.02	0.03	0.03	0.02	0.03	0.02	0.02	0.01	0.02	0.01	0.00	0.01	0.30
2.1-4.0	0.15	0.08	0.11	0.02	0.10	0.03	0.22	0.09	0.08	0.05	0.09	0.09	0.10	0.12	0.03	0.07	1.44
4.1-6.0	0.13	0.15	0.24	0.30	0.22	0.08	0.23	0.13	0.14	0.06	0.16	0.14	0.16	0.18	0.05	0.05	2.42
6.1-8.0	0.01	0.00	0.03	0.03	0.01	0.01	0.03	0.02	0.02	0.02	0.04	0.00	0.03	0.02	0.00	0.01	0.29
8.1-12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ATMOSPHERIC STABILITY CLASS G (VERY STABLE)																	
0.0-2.0	0.00	0.01	0.01	0.00	0.01	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.14
2.1-4.0	0.00	0.07	0.26	0.01	0.01	0.01	0.10	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.50
4.1-6.0	0.00	0.00	0.07	0.01	0.00	0.01	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.18
6.1-8.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
8.1-12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ALL CLASSES																	
All classes	3.06	2.94	5.08	6.57	7.23	6.31	6.52	5.62	5.77	6.08	6.90	6.76	8.42	9.15	8.59	4.97	

Table G-2. Annual Average Meteorological Dispersion/Deposition Parameters Within 80 Kilometers of SRP Center for Ground-Level Releases

	Distance (km)									
Direction from site	0-2	2-3	3-5	5-6	6-8	8-16	16-32	32-48	48-64	64-80
ANNUAL AVERAGE X/Q, UNDECAYED AND UNDEPLETED (sec/m ³)										
N	8.254 x 10 ⁻⁷	2.524 x 10 ⁻⁷	1.084 x 10 ⁻⁷	6.403 x 10 ⁻⁸	4.365 x 10 ⁻⁸	2.117 x 10 ⁻⁸	7.908 x 10 ⁻⁹	3.881 x 10 ⁻⁹	2.468 x 10 ⁻⁹	1.769 x 10 ⁻⁹
NNE	7.390 x 10 ⁻⁷	2.245 x 10 ⁻⁷	9.554 x 10 ⁻⁸	5.606 x 10 ⁻⁸	3.802 x 10 ⁻⁸	1.827 x 10 ⁻⁸	6.741 x 10 ⁻⁹	3.291 x 10 ⁻⁹	2.089 x 10 ⁻⁹	1.495 x 10 ⁻⁹
NE	9.494 x 10 ⁻⁷	2.912 x 10 ⁻⁷	1.251 x 10 ⁻⁷	7.389 x 10 ⁻⁸	5.035 x 10 ⁻⁸	2.434 x 10 ⁻⁸	9.042 x 10 ⁻⁹	4.417 x 10 ⁻⁹	2.800 x 10 ⁻⁹	2.002 x 10 ⁻⁹
ENE	9.499 x 10 ⁻⁷	2.902 x 10 ⁻⁷	1.241 x 10 ⁻⁷	7.304 x 10 ⁻⁸	4.966 x 10 ⁻⁸	2.397 x 10 ⁻⁸	8.882 x 10 ⁻⁹	4.330 x 10 ⁻⁹	2.742 x 10 ⁻⁹	1.959 x 10 ⁻⁹
E	1.227 x 10 ⁻⁶	3.746 x 10 ⁻⁷	1.605 x 10 ⁻⁷	9.473 x 10 ⁻⁸	6.453 x 10 ⁻⁸	3.125 x 10 ⁻⁸	1.167 x 10 ⁻⁸	5.747 x 10 ⁻⁹	3.666 x 10 ⁻⁹	2.634 x 10 ⁻⁹
ESE	1.156 x 10 ⁻⁶	3.503 x 10 ⁻⁷	1.486 x 10 ⁻⁷	8.699 x 10 ⁻⁸	5.889 x 10 ⁻⁸	2.824 x 10 ⁻⁸	1.039 x 10 ⁻⁸	5.068 x 10 ⁻⁹	3.216 x 10 ⁻⁹	2.302 x 10 ⁻⁹
SE	9.465 x 10 ⁻⁷	2.866 x 10 ⁻⁷	1.213 x 10 ⁻⁷	7.079 x 10 ⁻⁸	4.781 x 10 ⁻⁸	2.282 x 10 ⁻⁸	8.327 x 10 ⁻⁹	4.029 x 10 ⁻⁹	2.544 x 10 ⁻⁹	1.814 x 10 ⁻⁹
SSE	6.359 x 10 ⁻⁷	1.918 x 10 ⁻⁷	8.127 x 10 ⁻⁸	4.757 x 10 ⁻⁸	3.221 x 10 ⁻⁸	1.548 x 10 ⁻⁸	5.727 x 10 ⁻⁹	2.813 x 10 ⁻⁹	1.793 x 10 ⁻⁹	1.288 x 10 ⁻⁹
S	4.705 x 10 ⁻⁷	1.433 x 10 ⁻⁷	6.196 x 10 ⁻⁸	3.681 x 10 ⁻⁸	2.522 x 10 ⁻⁸	1.236 x 10 ⁻⁸	4.709 x 10 ⁻⁹	2.353 x 10 ⁻⁹	1.515 x 10 ⁻⁹	1.095 x 10 ⁻⁹
SSW	5.057 x 10 ⁻⁷	1.551 x 10 ⁻⁷	6.730 x 10 ⁻⁸	4.009 x 10 ⁻⁸	2.752 x 10 ⁻⁸	1.351 x 10 ⁻⁸	5.156 x 10 ⁻⁹	2.576 x 10 ⁻⁹	1.656 x 10 ⁻⁹	1.197 x 10 ⁻⁹
SW	9.776 x 10 ⁻⁷	3.013 x 10 ⁻⁷	1.313 x 10 ⁻⁷	7.850 x 10 ⁻⁸	5.404 x 10 ⁻⁸	2.666 x 10 ⁻⁸	1.025 x 10 ⁻⁸	5.149 x 10 ⁻⁹	3.322 x 10 ⁻⁹	2.407 x 10 ⁻⁹
WSW	8.207 x 10 ⁻⁷	2.479 x 10 ⁻⁷	1.048 x 10 ⁻⁷	6.127 x 10 ⁻⁸	4.144 x 10 ⁻⁸	1.984 x 10 ⁻⁸	7.307 x 10 ⁻⁹	3.576 x 10 ⁻⁹	2.276 x 10 ⁻⁹	1.632 x 10 ⁻⁹
W	9.536 x 10 ⁻⁷	2.893 x 10 ⁻⁷	1.230 x 10 ⁻⁷	7.213 x 10 ⁻⁸	4.892 x 10 ⁻⁸	2.354 x 10 ⁻⁸	8.718 x 10 ⁻⁹	4.276 x 10 ⁻⁹	2.722 x 10 ⁻⁹	1.953 x 10 ⁻⁹
WNW	7.890 x 10 ⁻⁷	2.378 x 10 ⁻⁷	1.007 x 10 ⁻⁷	5.889 x 10 ⁻⁸	3.987 x 10 ⁻⁸	1.917 x 10 ⁻⁸	7.106 x 10 ⁻⁹	3.494 x 10 ⁻⁹	2.229 x 10 ⁻⁹	1.603 x 10 ⁻⁹
NW	1.103 x 10 ⁻⁶	3.407 x 10 ⁻⁷	1.484 x 10 ⁻⁷	8.866 x 10 ⁻⁸	6.096 x 10 ⁻⁸	2.997 x 10 ⁻⁸	1.144 x 10 ⁻⁸	5.699 x 10 ⁻⁹	3.657 x 10 ⁻⁹	2.638 x 10 ⁻⁹
NNW	7.672 x 10 ⁻⁷	2.342 x 10 ⁻⁷	1.003 x 10 ⁻⁷	5.907 x 10 ⁻⁸	4.019 x 10 ⁻⁸	1.939 x 10 ⁻⁸	7.193 x 10 ⁻⁹	3.517 x 10 ⁻⁹	2.233 x 10 ⁻⁹	1.598 x 10 ⁻⁹
ANNUAL AVERAGE X/Q, DECAYED AND UNDEPLETED (sec/m ³)										
N	8.235 x 10 ⁻⁷	2.513 x 10 ⁻⁷	1.076 x 10 ⁻⁷	6.334 x 10 ⁻⁸	4.304 x 10 ⁻⁸	2.070 x 10 ⁻⁸	7.557 x 10 ⁻⁹	3.592 x 10 ⁻⁹	2.214 x 10 ⁻⁹	1.538 x 10 ⁻⁹
NNE	7.375 x 10 ⁻⁷	2.236 x 10 ⁻⁷	9.490 x 10 ⁻⁸	5.553 x 10 ⁻⁸	3.756 x 10 ⁻⁸	1.791 x 10 ⁻⁸	6.477 x 10 ⁻⁹	3.073 x 10 ⁻⁹	1.896 x 10 ⁻⁹	1.320 x 10 ⁻⁹
NE	9.476 x 10 ⁻⁷	2.901 x 10 ⁻⁷	1.243 x 10 ⁻⁷	7.322 x 10 ⁻⁸	4.976 x 10 ⁻⁸	2.388 x 10 ⁻⁸	8.701 x 10 ⁻⁹	4.135 x 10 ⁻⁹	2.552 x 10 ⁻⁹	1.776 x 10 ⁻⁹
ENE	9.479 x 10 ⁻⁷	2.890 x 10 ⁻⁷	1.232 x 10 ⁻⁷	7.231 x 10 ⁻⁸	4.902 x 10 ⁻⁸	2.347 x 10 ⁻⁸	8.514 x 10 ⁻⁹	4.028 x 10 ⁻⁹	2.477 x 10 ⁻⁹	1.719 x 10 ⁻⁹
E	1.224 x 10 ⁻⁶	3.729 x 10 ⁻⁷	1.593 x 10 ⁻⁷	9.367 x 10 ⁻⁸	6.361 x 10 ⁻⁸	3.052 x 10 ⁻⁸	1.113 x 10 ⁻⁸	5.297 x 10 ⁻⁹	3.268 x 10 ⁻⁹	2.271 x 10 ⁻⁹
ESE	1.154 x 10 ⁻⁶	3.488 x 10 ⁻⁷	1.476 x 10 ⁻⁷	8.613 x 10 ⁻⁸	5.815 x 10 ⁻⁸	2.766 x 10 ⁻⁸	9.970 x 10 ⁻⁹	4.721 x 10 ⁻⁹	2.909 x 10 ⁻⁹	2.023 x 10 ⁻⁹
SE	9.447 x 10 ⁻⁷	2.856 x 10 ⁻⁷	1.205 x 10 ⁻⁷	7.014 x 10 ⁻⁸	4.725 x 10 ⁻⁸	2.238 x 10 ⁻⁸	8.005 x 10 ⁻⁹	3.764 x 10 ⁻⁹	2.310 x 10 ⁻⁹	1.602 x 10 ⁻⁹

Table G-2. Annual Average Meteorological Dispersion/Deposition Parameters Within 80 Kilometers of SRP Center for Ground-Level Releases (continued)

Direction from site	Distance (km)									
	0-2	2-3	3-5	5-6	6-8	8-16	16-32	32-48	48-64	64-80
ANNUAL AVERAGE X/Q, DECAYED AND UNDEPLETED (sec/m ³) (continued)										
SSE	6.345 x 10 ⁻⁷	1.910 x 10 ⁻⁷	8.068 x 10 ⁻⁸	4.708 x 10 ⁻⁸	3.179 x 10 ⁻⁸	1.515 x 10 ⁻⁸	5.484 x 10 ⁻⁹	2.611 x 10 ⁻⁹	1.615 x 10 ⁻⁹	1.125 x 10 ⁻⁹
S	4.694 x 10 ⁻⁷	1.427 x 10 ⁻⁷	6.148 x 10 ⁻⁸	3.641 x 10 ⁻⁸	2.487 x 10 ⁻⁸	1.208 x 10 ⁻⁸	4.497 x 10 ⁻⁹	2.175 x 10 ⁻⁹	1.355 x 10 ⁻⁹	9.491 x 10 ⁻¹⁰
SSW	5.045 x 10 ⁻⁷	1.544 x 10 ⁻⁷	6.677 x 10 ⁻⁸	3.965 x 10 ⁻⁸	2.713 x 10 ⁻⁸	1.321 x 10 ⁻⁸	4.925 x 10 ⁻⁹	2.382 x 10 ⁻⁹	1.484 x 10 ⁻⁹	1.039 x 10 ⁻⁹
SW	9.755 x 10 ⁻⁷	2.999 x 10 ⁻⁷	1.303 x 10 ⁻⁷	7.768 x 10 ⁻⁸	5.332 x 10 ⁻⁸	2.609 x 10 ⁻⁸	9.816 x 10 ⁻⁹	4.786 x 10 ⁻⁹	2.999 x 10 ⁻⁹	2.110 x 10 ⁻⁹
WSW	8.191 x 10 ⁻⁷	2.470 x 10 ⁻⁷	1.042 x 10 ⁻⁷	6.072 x 10 ⁻⁸	4.096 x 10 ⁻⁸	1.948 x 10 ⁻⁸	7.038 x 10 ⁻⁹	3.355 x 10 ⁻⁹	2.080 x 10 ⁻⁹	1.454 x 10 ⁻⁹
W	9.518 x 10 ⁻⁷	2.882 x 10 ⁻⁷	1.221 x 10 ⁻⁷	7.145 x 10 ⁻⁸	4.833 x 10 ⁻⁸	2.308 x 10 ⁻⁸	8.379 x 10 ⁻⁹	3.996 x 10 ⁻⁹	2.475 x 10 ⁻⁹	1.727 x 10 ⁻⁹
WNW	7.874 x 10 ⁻⁷	2.368 x 10 ⁻⁷	9.997 x 10 ⁻⁸	5.832 x 10 ⁻⁸	3.937 x 10 ⁻⁸	1.879 x 10 ⁻⁸	6.819 x 10 ⁻⁹	3.255 x 10 ⁻⁹	2.017 x 10 ⁻⁹	1.408 x 10 ⁻⁹
NW	1.101 x 10 ⁻⁶	3.392 x 10 ⁻⁷	1.474 x 10 ⁻⁷	8.774 x 10 ⁻⁸	6.015 x 10 ⁻⁸	2.932 x 10 ⁻⁸	1.094 x 10 ⁻⁸	5.287 x 10 ⁻⁹	3.291 x 10 ⁻⁹	2.303 x 10 ⁻⁹
NNW	7.657 x 10 ⁻⁷	2.332 x 10 ⁻⁷	9.959 x 10 ⁻⁸	5.851 x 10 ⁻⁸	3.969 x 10 ⁻⁸	1.901 x 10 ⁻⁸	6.910 x 10 ⁻⁹	3.283 x 10 ⁻⁹	2.027 x 10 ⁻⁹	1.411 x 10 ⁻⁹
ANNUAL AVERAGE X/Q, DECAYED AND DEPLETED (sec/m ³)										
N	7.396 x 10 ⁻⁷	2.154 x 10 ⁻⁷	8.784 x 10 ⁻⁸	4.988 x 10 ⁻⁸	3.290 x 10 ⁻⁸	1.496 x 10 ⁻⁸	4.918 x 10 ⁻⁹	2.112 x 10 ⁻⁹	1.212 x 10 ⁻⁹	7.949 x 10 ⁻¹⁰
NNE	6.623 x 10 ⁻⁷	1.916 x 10 ⁻⁷	7.745 x 10 ⁻⁸	4.369 x 10 ⁻⁸	2.868 x 10 ⁻⁸	1.293 x 10 ⁻⁸	4.200 x 10 ⁻⁹	1.795 x 10 ⁻⁹	1.029 x 10 ⁻⁹	6.749 x 10 ⁻¹⁰
NE	8.508 x 10 ⁻⁷	2.485 x 10 ⁻⁷	1.014 x 10 ⁻⁷	5.759 x 10 ⁻⁸	3.798 x 10 ⁻⁸	1.723 x 10 ⁻⁸	5.635 x 10 ⁻⁹	2.411 x 10 ⁻⁹	1.381 x 10 ⁻⁹	9.050 x 10 ⁻¹⁰
ENE	8.512 x 10 ⁻⁷	2.476 x 10 ⁻⁷	1.006 x 10 ⁻⁷	5.692 x 10 ⁻⁸	3.744 x 10 ⁻⁸	1.695 x 10 ⁻⁸	5.530 x 10 ⁻⁹	2.360 x 10 ⁻⁹	1.349 x 10 ⁻⁹	8.827 x 10 ⁻¹⁰
E	1.100 x 10 ⁻⁶	3.196 x 10 ⁻⁷	1.301 x 10 ⁻⁷	7.379 x 10 ⁻⁸	4.864 x 10 ⁻⁸	2.208 x 10 ⁻⁸	7.253 x 10 ⁻⁹	3.124 x 10 ⁻⁹	1.796 x 10 ⁻⁹	1.181 x 10 ⁻⁹
ESE	1.036 x 10 ⁻⁶	2.990 x 10 ⁻⁷	1.204 x 10 ⁻⁷	6.779 x 10 ⁻⁸	4.441 x 10 ⁻⁸	1.997 x 10 ⁻⁸	6.472 x 10 ⁻⁹	2.763 x 10 ⁻⁹	1.583 x 10 ⁻⁹	1.038 x 10 ⁻⁹
SE	8.483 x 10 ⁻⁷	2.447 x 10 ⁻⁷	9.830 x 10 ⁻⁸	5.518 x 10 ⁻⁸	3.607 x 10 ⁻⁸	1.615 x 10 ⁻⁸	5.190 x 10 ⁻⁹	2.199 x 10 ⁻⁹	1.253 x 10 ⁻⁹	8.190 x 10 ⁻¹⁰
SSE	5.699 x 10 ⁻⁷	1.637 x 10 ⁻⁷	6.587 x 10 ⁻⁸	3.706 x 10 ⁻⁸	2.429 x 10 ⁻⁸	1.094 x 10 ⁻⁸	3.564 x 10 ⁻⁹	1.532 x 10 ⁻⁹	8.813 x 10 ⁻¹⁰	5.798 x 10 ⁻¹⁰
S	4.216 x 10 ⁻⁷	1.223 x 10 ⁻⁷	5.021 x 10 ⁻⁸	2.868 x 10 ⁻⁸	1.901 x 10 ⁻⁸	8.734 x 10 ⁻⁹	2.926 x 10 ⁻⁹	1.280 x 10 ⁻⁹	7.429 x 10 ⁻¹⁰	4.918 x 10 ⁻¹⁰
SSW	4.532 x 10 ⁻⁷	1.323 x 10 ⁻⁷	5.453 x 10 ⁻⁸	3.123 x 10 ⁻⁸	2.074 x 10 ⁻⁸	9.548 x 10 ⁻⁹	3.205 x 10 ⁻⁹	1.401 x 10 ⁻⁹	8.128 x 10 ⁻¹⁰	5.378 x 10 ⁻¹⁰
SW	8.761 x 10 ⁻⁷	2.570 x 10 ⁻⁷	1.064 x 10 ⁻⁷	6.115 x 10 ⁻⁸	4.074 x 10 ⁻⁸	1.884 x 10 ⁻⁸	6.374 x 10 ⁻⁹	2.805 x 10 ⁻⁹	1.634 x 10 ⁻⁹	1.084 x 10 ⁻⁹
WSW	7.355 x 10 ⁻⁷	2.116 x 10 ⁻⁷	8.499 x 10 ⁻⁸	4.776 x 10 ⁻⁸	3.126 x 10 ⁻⁸	1.405 x 10 ⁻⁸	4.555 x 10 ⁻⁹	1.953 x 10 ⁻⁹	1.123 x 10 ⁻⁹	7.387 x 10 ⁻¹⁰
W	8.547 x 10 ⁻⁷	2.469 x 10 ⁻⁷	9.967 x 10 ⁻⁸	5.621 x 10 ⁻⁸	3.690 x 10 ⁻⁸	1.665 x 10 ⁻⁸	5.431 x 10 ⁻⁹	2.333 x 10 ⁻⁹	1.341 x 10 ⁻⁹	8.821 x 10 ⁻¹⁰
WNW	7.071 x 10 ⁻⁷	2.030 x 10 ⁻⁷	8.159 x 10 ⁻⁸	4.589 x 10 ⁻⁸	3.007 x 10 ⁻⁸	1.356 x 10 ⁻⁸	4.425 x 10 ⁻⁹	1.905 x 10 ⁻⁹	1.097 x 10 ⁻⁹	7.225 x 10 ⁻¹⁰
NW	9.889 x 10 ⁻⁷	2.907 x 10 ⁻⁷	1.203 x 10 ⁻⁷	6.907 x 10 ⁻⁸	4.596 x 10 ⁻⁸	2.118 x 10 ⁻⁸	7.111 x 10 ⁻⁹	3.103 x 10 ⁻⁹	1.797 x 10 ⁻⁹	1.187 x 10 ⁻⁹
NNW	6.876 x 10 ⁻⁷	1.999 x 10 ⁻⁷	8.127 x 10 ⁻⁸	4.604 x 10 ⁻⁸	3.031 x 10 ⁻⁸	1.372 x 10 ⁻⁸	4.481 x 10 ⁻⁹	1.919 x 10 ⁻⁹	1.100 x 10 ⁻⁹	7.215 x 10 ⁻¹⁰

Table G-2. Annual Average Meteorological Dispersion/Deposition Parameters Within 80 Kilometers of SRP Center for Ground-Level Releases (continued)

		Distance (km)									
Direction from site		0-2	2-3	3-5	5-6	6-8	8-16	16-32	32-48	48-64	64-80
ANNUAL AVERAGE D/Q (m ⁻²)											
8-G	N	6.024 x 10 ⁻⁹	1.861 x 10 ⁻⁹	7.406 x 10 ⁻¹⁰	4.047 x 10 ⁻¹⁰	2.572 x 10 ⁻¹⁰	1.105 x 10 ⁻¹⁰	3.426 x 10 ⁻¹¹	1.358 x 10 ⁻¹¹	7.251 x 10 ⁻¹²	4.488 x 10 ⁻¹²
	NNE	6.351 x 10 ⁻⁹	1.962 x 10 ⁻⁹	7.808 x 10 ⁻¹⁰	4.267 x 10 ⁻¹⁰	2.712 x 10 ⁻¹⁰	1.165 x 10 ⁻¹⁰	3.612 x 10 ⁻¹¹	1.432 x 10 ⁻¹¹	7.645 x 10 ⁻¹²	4.732 x 10 ⁻¹²
	NE	7.209 x 10 ⁻⁹	2.227 x 10 ⁻⁹	8.863 x 10 ⁻¹⁰	4.843 x 10 ⁻¹⁰	3.078 x 10 ⁻¹⁰	1.322 x 10 ⁻¹⁰	4.100 x 10 ⁻¹¹	1.625 x 10 ⁻¹¹	8.678 x 10 ⁻¹²	5.371 x 10 ⁻¹²
	ENE	7.064 x 10 ⁻⁹	2.182 x 10 ⁻⁹	8.684 x 10 ⁻¹⁰	4.746 x 10 ⁻¹⁰	3.016 x 10 ⁻¹⁰	1.296 x 10 ⁻¹⁰	4.017 x 10 ⁻¹¹	1.592 x 10 ⁻¹¹	8.503 x 10 ⁻¹²	5.263 x 10 ⁻¹²
	E	8.791 x 10 ⁻⁹	2.716 x 10 ⁻⁹	1.081 x 10 ⁻⁹	5.906 x 10 ⁻¹⁰	3.754 x 10 ⁻¹⁰	1.612 x 10 ⁻¹⁰	5.000 x 10 ⁻¹¹	1.982 x 10 ⁻¹¹	1.058 x 10 ⁻¹¹	6.550 x 10 ⁻¹²
	ESE	9.561 x 10 ⁻⁹	2.954 x 10 ⁻⁹	1.175 x 10 ⁻⁹	6.423 x 10 ⁻¹⁰	4.083 x 10 ⁻¹⁰	1.754 x 10 ⁻¹⁰	5.438 x 10 ⁻¹¹	2.155 x 10 ⁻¹¹	1.151 x 10 ⁻¹¹	7.124 x 10 ⁻¹²
	SE	8.976 x 10 ⁻⁹	2.773 x 10 ⁻⁹	1.104 x 10 ⁻⁹	6.030 x 10 ⁻¹⁰	3.833 x 10 ⁻¹⁰	1.646 x 10 ⁻¹⁰	5.105 x 10 ⁻¹¹	2.023 x 10 ⁻¹¹	1.080 x 10 ⁻¹¹	6.688 x 10 ⁻¹²
	SSE	5.195 x 10 ⁻⁹	1.605 x 10 ⁻⁹	6.387 x 10 ⁻¹⁰	3.490 x 10 ⁻¹⁰	2.218 x 10 ⁻¹⁰	9.528 x 10 ⁻¹¹	2.955 x 10 ⁻¹¹	1.171 x 10 ⁻¹¹	6.254 x 10 ⁻¹²	3.871 x 10 ⁻¹²
	S	3.199 x 10 ⁻⁹	9.884 x 10 ⁻¹⁰	3.933 x 10 ⁻¹⁰	2.149 x 10 ⁻¹⁰	1.366 x 10 ⁻¹⁰	5.868 x 10 ⁻¹¹	1.820 x 10 ⁻¹¹	7.212 x 10 ⁻¹²	3.851 x 10 ⁻¹²	2.384 x 10 ⁻¹²
	SSW	3.072 x 10 ⁻⁹	9.491 x 10 ⁻¹⁰	3.777 x 10 ⁻¹⁰	2.064 x 10 ⁻¹⁰	1.312 x 10 ⁻¹⁰	5.634 x 10 ⁻¹¹	1.747 x 10 ⁻¹¹	6.925 x 10 ⁻¹²	3.698 x 10 ⁻¹²	2.289 x 10 ⁻¹²
	SW	5.308 x 10 ⁻⁹	1.640 x 10 ⁻⁹	6.525 x 10 ⁻¹⁰	3.566 x 10 ⁻¹⁰	2.266 x 10 ⁻¹⁰	9.735 x 10 ⁻¹¹	3.019 x 10 ⁻¹¹	1.196 x 10 ⁻¹¹	6.389 x 10 ⁻¹²	3.955 x 10 ⁻¹²
	WSW	6.867 x 10 ⁻⁹	2.122 x 10 ⁻⁹	8.443 x 10 ⁻¹⁰	4.614 x 10 ⁻¹⁰	2.932 x 10 ⁻¹⁰	1.260 x 10 ⁻¹⁰	3.906 x 10 ⁻¹¹	1.548 x 10 ⁻¹¹	8.267 x 10 ⁻¹²	5.117 x 10 ⁻¹²
	W	7.555 x 10 ⁻⁹	2.334 x 10 ⁻⁹	9.288 x 10 ⁻¹⁰	5.075 x 10 ⁻¹⁰	3.226 x 10 ⁻¹⁰	1.386 x 10 ⁻¹⁰	4.297 x 10 ⁻¹¹	1.703 x 10 ⁻¹¹	9.094 x 10 ⁻¹²	5.629 x 10 ⁻¹²
	WNW	6.595 x 10 ⁻⁹	2.037 x 10 ⁻⁹	8.108 x 10 ⁻¹⁰	4.430 x 10 ⁻¹⁰	2.816 x 10 ⁻¹⁰	1.210 x 10 ⁻¹⁰	3.751 x 10 ⁻¹¹	1.487 x 10 ⁻¹¹	7.938 x 10 ⁻¹²	4.914 x 10 ⁻¹²
	NW	6.813 x 10 ⁻⁹	2.105 x 10 ⁻⁹	8.376 x 10 ⁻¹⁰	4.577 x 10 ⁻¹⁰	2.909 x 10 ⁻¹⁰	1.250 x 10 ⁻¹⁰	3.875 x 10 ⁻¹¹	1.536 x 10 ⁻¹¹	8.201 x 10 ⁻¹²	5.076 x 10 ⁻¹²
	NNW	5.875 x 10 ⁻⁹	1.815 x 10 ⁻⁹	7.223 x 10 ⁻¹⁰	3.947 x 10 ⁻¹⁰	2.509 x 10 ⁻¹⁰	1.078 x 10 ⁻¹⁰	3.341 x 10 ⁻¹¹	1.324 x 10 ⁻¹¹	7.072 x 10 ⁻¹²	4.377 x 10 ⁻¹²

Table G-3. Annual Average Meteorological Dispersion/Deposition Parameters Within 80 Kilometers of SRP Center for Elevated Releases

Direction from site	Distance (km)									
	0-2	2-3	3-5	5-6	6-8	8-16	16-32	32-48	48-64	64-80
ANNUAL AVERAGE X/Q, UNDECAYED AND UNDEPLETED (sec/m ³)										
N	1.657 x 10 ⁻⁷	9.830 x 10 ⁻⁸	6.035 x 10 ⁻⁸	4.110 x 10 ⁻⁸	3.030 x 10 ⁻⁸	1.617 x 10 ⁻⁸	6.688 x 10 ⁻⁹	3.455 x 10 ⁻⁹	2.246 x 10 ⁻⁹	1.630 x 10 ⁻⁹
NNE	1.715 x 10 ⁻⁷	9.824 x 10 ⁻⁸	5.792 x 10 ⁻⁸	3.855 x 10 ⁻⁸	2.800 x 10 ⁻⁸	1.461 x 10 ⁻⁸	5.878 x 10 ⁻⁹	2.997 x 10 ⁻⁹	1.938 x 10 ⁻⁹	1.402 x 10 ⁻⁹
NE	1.851 x 10 ⁻⁷	1.140 x 10 ⁻⁷	7.034 x 10 ⁻⁸	4.786 x 10 ⁻⁸	3.523 x 10 ⁻⁸	1.870 x 10 ⁻⁸	7.660 x 10 ⁻⁹	3.931 x 10 ⁻⁹	2.546 x 10 ⁻⁹	1.843 x 10 ⁻⁹
ENE	1.979 x 10 ⁻⁷	1.186 x 10 ⁻⁷	7.223 x 10 ⁻⁸	4.881 x 10 ⁻⁸	3.578 x 10 ⁻⁸	1.891 x 10 ⁻⁸	7.703 x 10 ⁻⁹	3.936 x 10 ⁻⁹	2.542 x 10 ⁻⁹	1.837 x 10 ⁻⁹
E	2.592 x 10 ⁻⁷	1.492 x 10 ⁻⁷	8.848 x 10 ⁻⁸	5.922 x 10 ⁻⁸	4.323 x 10 ⁻⁸	2.278 x 10 ⁻⁸	9.331 x 10 ⁻⁹	4.829 x 10 ⁻⁹	3.150 x 10 ⁻⁹	2.294 x 10 ⁻⁹
ESE	2.821 x 10 ⁻⁷	1.583 x 10 ⁻⁷	9.177 x 10 ⁻⁸	6.061 x 10 ⁻⁸	4.382 x 10 ⁻⁸	2.274 x 10 ⁻⁸	9.098 x 10 ⁻⁹	4.628 x 10 ⁻⁹	2.990 x 10 ⁻⁹	2.162 x 10 ⁻⁹
SE	2.365 x 10 ⁻⁷	1.357 x 10 ⁻⁷	7.860 x 10 ⁻⁸	5.161 x 10 ⁻⁸	3.711 x 10 ⁻⁸	1.904 x 10 ⁻⁸	7.490 x 10 ⁻⁹	3.757 x 10 ⁻⁹	2.407 x 10 ⁻⁹	1.731 x 10 ⁻⁹
SSE	1.609 x 10 ⁻⁷	8.715 x 10 ⁻⁸	5.018 x 10 ⁻⁸	3.311 x 10 ⁻⁸	2.394 x 10 ⁻⁸	1.246 x 10 ⁻⁸	5.017 x 10 ⁻⁹	2.571 x 10 ⁻⁹	1.669 x 10 ⁻⁹	1.212 x 10 ⁻⁹
S	9.942 x 10 ⁻⁸	5.287 x 10 ⁻⁸	3.174 x 10 ⁻⁸	2.172 x 10 ⁻⁸	1.615 x 10 ⁻⁸	8.804 x 10 ⁻⁹	3.772 x 10 ⁻⁹	2.007 x 10 ⁻⁹	1.329 x 10 ⁻⁹	9.773 x 10 ⁻¹⁰
SSW	9.513 x 10 ⁻⁸	5.374 x 10 ⁻⁸	3.282 x 10 ⁻⁸	2.247 x 10 ⁻⁸	1.669 x 10 ⁻⁸	9.063 x 10 ⁻⁹	3.867 x 10 ⁻⁹	2.055 x 10 ⁻⁹	1.360 x 10 ⁻⁹	1.000 x 10 ⁻⁹
SW	1.629 x 10 ⁻⁷	9.250 x 10 ⁻⁸	5.601 x 10 ⁻⁸	3.832 x 10 ⁻⁸	2.850 x 10 ⁻⁸	1.560 x 10 ⁻⁸	6.776 x 10 ⁻⁹	3.661 x 10 ⁻⁹	2.449 x 10 ⁻⁹	1.815 x 10 ⁻⁹
WSW	2.038 x 10 ⁻⁷	1.107 x 10 ⁻⁷	6.305 x 10 ⁻⁸	4.144 x 10 ⁻⁸	2.991 x 10 ⁻⁸	1.553 x 10 ⁻⁸	6.242 x 10 ⁻⁹	3.200 x 10 ⁻⁹	2.078 x 10 ⁻⁹	1.508 x 10 ⁻⁹
W	2.212 x 10 ⁻⁷	1.229 x 10 ⁻⁷	7.136 x 10 ⁻⁸	4.735 x 10 ⁻⁸	3.438 x 10 ⁻⁸	1.800 x 10 ⁻⁸	7.305 x 10 ⁻⁹	3.760 x 10 ⁻⁹	2.445 x 10 ⁻⁹	1.777 x 10 ⁻⁹
WNW	2.032 x 10 ⁻⁷	1.085 x 10 ⁻⁷	6.167 x 10 ⁻⁸	4.047 x 10 ⁻⁸	2.918 x 10 ⁻⁸	1.515 x 10 ⁻⁸	6.103 x 10 ⁻⁹	3.132 x 10 ⁻⁹	2.036 x 10 ⁻⁹	1.480 x 10 ⁻⁹
NW	1.796 x 10 ⁻⁷	1.080 x 10 ⁻⁷	6.754 x 10 ⁻⁸	4.674 x 10 ⁻⁸	3.492 x 10 ⁻⁸	1.911 x 10 ⁻⁸	8.213 x 10 ⁻⁹	4.375 x 10 ⁻⁹	2.897 x 10 ⁻⁹	2.131 x 10 ⁻⁹
NNW	1.648 x 10 ⁻⁷	9.680 x 10 ⁻⁸	5.825 x 10 ⁻⁸	3.922 x 10 ⁻⁸	2.870 x 10 ⁻⁸	1.513 x 10 ⁻⁸	6.167 x 10 ⁻⁹	3.163 x 10 ⁻⁹	2.049 x 10 ⁻⁹	1.485 x 10 ⁻⁹
ANNUAL AVERAGE X/Q, DECAYED AND UNDEPLETED (sec/m ³)										
N	1.653 x 10 ⁻⁷	9.782 x 10 ⁻⁸	5.987 x 10 ⁻⁸	4.064 x 10 ⁻⁸	2.987 x 10 ⁻⁸	1.580 x 10 ⁻⁸	6.384 x 10 ⁻⁹	3.194 x 10 ⁻⁹	2.012 x 10 ⁻⁹	1.416 x 10 ⁻⁹
NNE	1.711 x 10 ⁻⁷	9.781 x 10 ⁻⁸	5.751 x 10 ⁻⁸	3.818 x 10 ⁻⁸	2.765 x 10 ⁻⁸	1.431 x 10 ⁻⁸	5.644 x 10 ⁻⁹	2.797 x 10 ⁻⁹	1.758 x 10 ⁻⁹	1.237 x 10 ⁻⁹
NE	1.846 x 10 ⁻⁷	1.135 x 10 ⁻⁷	6.986 x 10 ⁻⁸	4.741 x 10 ⁻⁸	3.481 x 10 ⁻⁸	1.833 x 10 ⁻⁸	7.366 x 10 ⁻⁹	3.679 x 10 ⁻⁹	2.319 x 10 ⁻⁹	1.634 x 10 ⁻⁹
ENE	1.974 x 10 ⁻⁷	1.181 x 10 ⁻⁷	7.168 x 10 ⁻⁸	4.831 x 10 ⁻⁸	3.530 x 10 ⁻⁸	1.850 x 10 ⁻⁸	7.377 x 10 ⁻⁹	3.658 x 10 ⁻⁹	2.294 x 10 ⁻⁹	1.610 x 10 ⁻⁹
E	2.586 x 10 ⁻⁷	1.484 x 10 ⁻⁷	8.779 x 10 ⁻⁸	5.858 x 10 ⁻⁸	4.263 x 10 ⁻⁸	2.227 x 10 ⁻⁸	8.914 x 10 ⁻⁹	4.466 x 10 ⁻⁹	2.822 x 10 ⁻⁹	1.990 x 10 ⁻⁹
ESE	2.813 x 10 ⁻⁷	1.575 x 10 ⁻⁷	9.108 x 10 ⁻⁸	5.998 x 10 ⁻⁸	4.324 x 10 ⁻⁸	2.225 x 10 ⁻⁸	8.716 x 10 ⁻⁹	4.304 x 10 ⁻⁹	2.700 x 10 ⁻⁹	1.896 x 10 ⁻⁹
SE	2.359 x 10 ⁻⁷	1.351 x 10 ⁻⁷	7.808 x 10 ⁻⁸	5.113 x 10 ⁻⁸	3.666 x 10 ⁻⁸	1.868 x 10 ⁻⁸	7.199 x 10 ⁻⁹	3.511 x 10 ⁻⁹	2.187 x 10 ⁻⁹	1.529 x 10 ⁻⁹

Table G-3. Annual Average Meteorological Dispersion/Deposition Parameters Within 80 Kilometers of SRP Center for Elevated Releases (continued)

Direction from site	Distance (km)									
	0-2	2-3	3-5	5-6	6-8	8-16	16-32	32-48	48-64	64-80
ANNUAL AVERAGE X/Q, DECAYED AND UNDEPLETED (sec/m ³) (continued)										
SSE	1.604 x 10 ⁻⁷	8.673 x 10 ⁻⁸	4.979 x 10 ⁻⁸	3.276 x 10 ⁻⁸	2.362 x 10 ⁻⁸	1.218 x 10 ⁻⁸	4.799 x 10 ⁻⁹	2.384 x 10 ⁻⁹	1.501 x 10 ⁻⁹	1.057 x 10 ⁻⁹
S	9.914 x 10 ⁻⁸	5.259 x 10 ⁻⁸	3.148 x 10 ⁻⁸	2.147 x 10 ⁻⁸	1.591 x 10 ⁻⁸	8.596 x 10 ⁻⁹	3.597 x 10 ⁻⁹	1.853 x 10 ⁻⁹	1.188 x 10 ⁻⁹	8.459 x 10 ⁻¹⁰
SSW	9.486 x 10 ⁻⁸	5.345 x 10 ⁻⁸	3.254 x 10 ⁻⁸	2.221 x 10 ⁻⁸	1.643 x 10 ⁻⁸	8.841 x 10 ⁻⁹	3.683 x 10 ⁻⁹	1.894 x 10 ⁻⁹	1.213 x 10 ⁻⁹	8.643 x 10 ⁻¹⁰
SW	1.624 x 10 ⁻⁷	9.201 x 10 ⁻⁸	5.553 x 10 ⁻⁸	3.787 x 10 ⁻⁸	2.807 x 10 ⁻⁸	1.523 x 10 ⁻⁸	6.462 x 10 ⁻⁹	3.384 x 10 ⁻⁹	2.195 x 10 ⁻⁹	1.578 x 10 ⁻⁹
WSW	2.033 x 10 ⁻⁷	1.103 x 10 ⁻⁷	6.261 x 10 ⁻⁸	4.105 x 10 ⁻⁸	2.955 x 10 ⁻⁸	1.523 x 10 ⁻⁸	6.004 x 10 ⁻⁹	2.997 x 10 ⁻⁹	1.895 x 10 ⁻⁹	1.340 x 10 ⁻⁹
W	2.207 x 10 ⁻⁷	1.224 x 10 ⁻⁷	7.087 x 10 ⁻⁸	4.690 x 10 ⁻⁸	3.397 x 10 ⁻⁸	1.765 x 10 ⁻⁸	7.021 x 10 ⁻⁹	3.515 x 10 ⁻⁹	2.225 x 10 ⁻⁹	1.573 x 10 ⁻⁹
WNW	2.027 x 10 ⁻⁷	1.080 x 10 ⁻⁷	6.124 x 10 ⁻⁸	4.008 x 10 ⁻⁸	2.882 x 10 ⁻⁸	1.485 x 10 ⁻⁸	5.856 x 10 ⁻⁹	2.918 x 10 ⁻⁹	1.843 x 10 ⁻⁹	1.301 x 10 ⁻⁹
NW	1.791 x 10 ⁻⁷	1.075 x 10 ⁻⁷	6.703 x 10 ⁻⁸	4.625 x 10 ⁻⁸	3.445 x 10 ⁻⁸	1.869 x 10 ⁻⁸	7.863 x 10 ⁻⁹	4.064 x 10 ⁻⁹	2.612 x 10 ⁻⁹	1.865 x 10 ⁻⁹
NNW	1.644 x 10 ⁻⁷	9.637 x 10 ⁻⁸	5.783 x 10 ⁻⁸	3.883 x 10 ⁻⁸	2.833 x 10 ⁻⁸	1.482 x 10 ⁻⁸	5.917 x 10 ⁻⁹	2.949 x 10 ⁻⁹	1.857 x 10 ⁻⁹	1.308 x 10 ⁻⁹
ANNUAL AVERAGE X/Q, DECAYED AND DEPLETED (sec/m ³)										
N	1.617 x 10 ⁻⁷	9.484 x 10 ⁻⁸	5.757 x 10 ⁻⁸	3.886 x 10 ⁻⁸	2.845 x 10 ⁻⁸	1.493 x 10 ⁻⁸	5.959 x 10 ⁻⁹	2.962 x 10 ⁻⁹	1.857 x 10 ⁻⁹	1.294 x 10 ⁻⁹
NNE	1.673 x 10 ⁻⁷	9.451 x 10 ⁻⁸	5.490 x 10 ⁻⁸	3.613 x 10 ⁻⁸	2.600 x 10 ⁻⁸	1.328 x 10 ⁻⁸	5.120 x 10 ⁻⁹	2.494 x 10 ⁻⁹	1.546 x 10 ⁻⁹	1.069 x 10 ⁻⁹
NE	1.807 x 10 ⁻⁷	1.100 x 10 ⁻⁷	6.711 x 10 ⁻⁸	4.524 x 10 ⁻⁸	3.305 x 10 ⁻⁸	1.724 x 10 ⁻⁸	6.824 x 10 ⁻⁹	3.375 x 10 ⁻⁹	2.112 x 10 ⁻⁹	1.472 x 10 ⁻⁹
ENE	1.931 x 10 ⁻⁷	1.145 x 10 ⁻⁷	6.882 x 10 ⁻⁸	4.606 x 10 ⁻⁸	3.349 x 10 ⁻⁸	1.738 x 10 ⁻⁸	6.820 x 10 ⁻⁹	3.348 x 10 ⁻⁹	2.084 x 10 ⁻⁹	1.446 x 10 ⁻⁹
E	2.528 x 10 ⁻⁷	1.435 x 10 ⁻⁷	8.396 x 10 ⁻⁸	5.561 x 10 ⁻⁸	4.024 x 10 ⁻⁸	2.080 x 10 ⁻⁸	8.195 x 10 ⁻⁹	4.068 x 10 ⁻⁹	2.554 x 10 ⁻⁹	1.783 x 10 ⁻⁹
ESE	2.750 x 10 ⁻⁷	1.520 x 10 ⁻⁷	8.673 x 10 ⁻⁸	5.655 x 10 ⁻⁸	4.046 x 10 ⁻⁸	2.051 x 10 ⁻⁸	7.833 x 10 ⁻⁹	3.791 x 10 ⁻⁹	2.342 x 10 ⁻⁹	1.615 x 10 ⁻⁹
SE	2.308 x 10 ⁻⁷	1.304 x 10 ⁻⁷	7.426 x 10 ⁻⁸	4.809 x 10 ⁻⁸	3.418 x 10 ⁻⁸	1.711 x 10 ⁻⁸	6.395 x 10 ⁻⁹	3.040 x 10 ⁻⁹	1.857 x 10 ⁻⁹	1.270 x 10 ⁻⁹
SSE	1.567 x 10 ⁻⁷	8.367 x 10 ⁻⁸	4.746 x 10 ⁻⁸	3.095 x 10 ⁻⁸	2.217 x 10 ⁻⁸	1.129 x 10 ⁻⁸	4.344 x 10 ⁻⁹	2.119 x 10 ⁻⁹	1.314 x 10 ⁻⁹	9.085 x 10 ⁻¹⁰
S	9.680 x 10 ⁻⁸	5.077 x 10 ⁻⁸	3.010 x 10 ⁻⁸	2.041 x 10 ⁻⁸	1.506 x 10 ⁻⁸	8.068 x 10 ⁻⁹	3.330 x 10 ⁻⁹	1.702 x 10 ⁻⁹	1.084 x 10 ⁻⁹	7.636 x 10 ⁻¹⁰
SSW	9.270 x 10 ⁻⁸	5.176 x 10 ⁻⁸	3.126 x 10 ⁻⁸	2.122 x 10 ⁻⁸	1.565 x 10 ⁻⁸	8.362 x 10 ⁻⁹	3.450 x 10 ⁻⁹	1.767 x 10 ⁻⁹	1.130 x 10 ⁻⁹	7.988 x 10 ⁻¹⁰
SW	1.587 x 10 ⁻⁷	8.906 x 10 ⁻⁸	5.332 x 10 ⁻⁸	3.619 x 10 ⁻⁸	2.674 x 10 ⁻⁸	1.444 x 10 ⁻⁸	6.092 x 10 ⁻⁹	3.193 x 10 ⁻⁹	2.075 x 10 ⁻⁹	1.487 x 10 ⁻⁹
WSW	1.985 x 10 ⁻⁷	1.062 x 10 ⁻⁷	5.949 x 10 ⁻⁸	3.862 x 10 ⁻⁸	2.760 x 10 ⁻⁸	1.402 x 10 ⁻⁸	5.392 x 10 ⁻⁹	2.638 x 10 ⁻⁹	1.642 x 10 ⁻⁹	1.139 x 10 ⁻⁹
W	2.156 x 10 ⁻⁷	1.181 x 10 ⁻⁷	6.755 x 10 ⁻⁸	4.433 x 10 ⁻⁸	3.190 x 10 ⁻⁸	1.637 x 10 ⁻⁸	6.379 x 10 ⁻⁹	3.144 x 10 ⁻⁹	1.965 x 10 ⁻⁹	1.368 x 10 ⁻⁹
WNW	1.980 x 10 ⁻⁷	1.041 x 10 ⁻⁷	5.819 x 10 ⁻⁸	3.770 x 10 ⁻⁸	2.690 x 10 ⁻⁸	1.365 x 10 ⁻⁸	5.239 x 10 ⁻⁹	2.555 x 10 ⁻⁹	1.585 x 10 ⁻⁹	1.096 x 10 ⁻⁹
NW	1.752 x 10 ⁻⁷	1.042 x 10 ⁻⁷	6.453 x 10 ⁻⁸	4.431 x 10 ⁻⁸	3.290 x 10 ⁻⁸	1.775 x 10 ⁻⁸	7.415 x 10 ⁻⁹	3.830 x 10 ⁻⁹	2.463 x 10 ⁻⁹	1.751 x 10 ⁻⁹
NNW	1.608 x 10 ⁻⁷	9.323 x 10 ⁻⁸	5.532 x 10 ⁻⁸	3.684 x 10 ⁻⁸	2.673 x 10 ⁻⁸	1.382 x 10 ⁻⁸	5.410 x 10 ⁻⁹	2.659 x 10 ⁻⁹	1.658 x 10 ⁻⁹	1.151 x 10 ⁻⁹

Table G-3. Annual Average Meteorological Dispersion/Deposition Parameters Within 80 Kilometers of SRP Center for Elevated Releases (continued)

Direction from site	Distance (km)									
	0-2	2-3	3-5	5-6	6-8	8-16	16-32	32-48	48-64	64-80
	ANNUAL AVERAGE D/Q (m ⁻²)									
N	2.473 x 10 ⁻⁹	9.109 x 10 ⁻¹⁰	4.045 x 10 ⁻¹⁰	2.331 x 10 ⁻¹⁰	1.539 x 10 ⁻¹⁰	6.845 x 10 ⁻¹¹	2.264 x 10 ⁻¹¹	1.049 x 10 ⁻¹¹	6.614 x 10 ⁻¹²	4.729 x 10 ⁻¹²
NNE	2.697 x 10 ⁻⁹	1.011 x 10 ⁻⁹	4.511 x 10 ⁻¹⁰	2.602 x 10 ⁻¹⁰	1.717 x 10 ⁻¹⁰	7.626 x 10 ⁻¹¹	2.506 x 10 ⁻¹¹	1.151 x 10 ⁻¹¹	7.194 x 10 ⁻¹²	5.100 x 10 ⁻¹²
NE	2.740 x 10 ⁻⁹	1.038 x 10 ⁻⁹	4.647 x 10 ⁻¹⁰	2.682 x 10 ⁻¹⁰	1.770 x 10 ⁻¹⁰	7.851 x 10 ⁻¹¹	2.569 x 10 ⁻¹¹	1.179 x 10 ⁻¹¹	7.421 x 10 ⁻¹²	5.323 x 10 ⁻¹²
ENE	2.811 x 10 ⁻⁹	1.059 x 10 ⁻⁹	4.737 x 10 ⁻¹⁰	2.733 x 10 ⁻¹⁰	1.804 x 10 ⁻¹⁰	8.005 x 10 ⁻¹¹	2.625 x 10 ⁻¹¹	1.205 x 10 ⁻¹¹	7.565 x 10 ⁻¹²	5.399 x 10 ⁻¹²
E	3.650 x 10 ⁻⁹	1.369 x 10 ⁻⁹	6.114 x 10 ⁻¹⁰	3.527 x 10 ⁻¹⁰	2.327 x 10 ⁻¹⁰	1.033 x 10 ⁻¹⁰	3.394 x 10 ⁻¹¹	1.559 x 10 ⁻¹¹	9.764 x 10 ⁻¹²	6.939 x 10 ⁻¹²
ESE	4.124 x 10 ⁻⁹	1.582 x 10 ⁻⁹	7.110 x 10 ⁻¹⁰	4.104 x 10 ⁻¹⁰	2.708 x 10 ⁻¹⁰	1.200 x 10 ⁻¹⁰	3.908 x 10 ⁻¹¹	1.776 x 10 ⁻¹¹	1.100 x 10 ⁻¹¹	7.739 x 10 ⁻¹²
SE	4.028 x 10 ⁻⁹	1.575 x 10 ⁻⁹	7.119 x 10 ⁻¹⁰	4.113 x 10 ⁻¹⁰	2.714 x 10 ⁻¹⁰	1.200 x 10 ⁻¹⁰	3.880 x 10 ⁻¹¹	1.747 x 10 ⁻¹¹	1.072 x 10 ⁻¹¹	7.461 x 10 ⁻¹²
SSE	2.366 x 10 ⁻⁹	8.707 x 10 ⁻¹⁰	3.865 x 10 ⁻¹⁰	2.228 x 10 ⁻¹⁰	1.470 x 10 ⁻¹⁰	6.541 x 10 ⁻¹¹	2.164 x 10 ⁻¹¹	9.996 x 10 ⁻¹²	6.248 x 10 ⁻¹²	4.412 x 10 ⁻¹²
S	1.385 x 10 ⁻⁹	4.897 x 10 ⁻¹⁰	2.146 x 10 ⁻¹⁰	1.235 x 10 ⁻¹⁰	8.152 x 10 ⁻¹¹	3.642 x 10 ⁻¹¹	1.224 x 10 ⁻¹¹	5.765 x 10 ⁻¹²	3.666 x 10 ⁻¹²	2.621 x 10 ⁻¹²
SSW	1.251 x 10 ⁻⁹	4.481 x 10 ⁻¹⁰	1.972 x 10 ⁻¹⁰	1.136 x 10 ⁻¹⁰	7.496 x 10 ⁻¹¹	3.344 x 10 ⁻¹¹	1.118 x 10 ⁻¹¹	5.246 x 10 ⁻¹²	3.340 x 10 ⁻¹²	2.407 x 10 ⁻¹²
SW	1.979 x 10 ⁻⁹	7.211 x 10 ⁻¹⁰	3.191 x 10 ⁻¹⁰	1.839 x 10 ⁻¹⁰	1.213 x 10 ⁻¹⁰	5.404 x 10 ⁻¹¹	1.796 x 10 ⁻¹¹	8.384 x 10 ⁻¹²	5.355 x 10 ⁻¹²	3.888 x 10 ⁻¹²
WSW	3.024 x 10 ⁻⁹	1.120 x 10 ⁻⁹	4.979 x 10 ⁻¹⁰	2.870 x 10 ⁻¹⁰	1.894 x 10 ⁻¹⁰	8.423 x 10 ⁻¹¹	2.780 x 10 ⁻¹¹	1.282 x 10 ⁻¹¹	8.021 x 10 ⁻¹²	5.678 x 10 ⁻¹²
W	3.342 x 10 ⁻⁹	1.228 x 10 ⁻⁹	5.447 x 10 ⁻¹⁰	3.139 x 10 ⁻¹⁰	2.072 x 10 ⁻¹⁰	9.220 x 10 ⁻¹¹	3.052 x 10 ⁻¹¹	1.412 x 10 ⁻¹¹	8.852 x 10 ⁻¹²	6.275 x 10 ⁻¹²
WNW	3.053 x 10 ⁻⁹	1.120 x 10 ⁻⁹	4.969 x 10 ⁻¹⁰	2.864 x 10 ⁻¹⁰	1.890 x 10 ⁻¹⁰	8.411 x 10 ⁻¹¹	2.785 x 10 ⁻¹¹	1.288 x 10 ⁻¹¹	8.043 x 10 ⁻¹²	5.673 x 10 ⁻¹²
NW	2.555 x 10 ⁻⁹	9.364 x 10 ⁻¹⁰	4.152 x 10 ⁻¹⁰	2.393 x 10 ⁻¹⁰	1.579 x 10 ⁻¹⁰	7.028 x 10 ⁻¹¹	2.330 x 10 ⁻¹¹	1.085 x 10 ⁻¹¹	6.912 x 10 ⁻¹²	5.008 x 10 ⁻¹²
NNW	2.415 x 10 ⁻⁹	9.062 x 10 ⁻¹⁰	4.047 x 10 ⁻¹⁰	2.334 x 10 ⁻¹⁰	1.540 x 10 ⁻¹⁰	6.840 x 10 ⁻¹¹	2.246 x 10 ⁻¹¹	1.032 x 10 ⁻¹¹	6.468 x 10 ⁻¹²	4.602 x 10 ⁻¹²

Table G-4. Population and Annual Food Production Within 80 Kilometers of the SRP Center^a

		Distance (km)					
Direction	0-8	8-16	16-32	32-48	48-64	64-80	0-80
POPULATION							
N	0	1,507	5,589	7,411	8,541	20,725	43,774
NNE	0	70	1,118	2,952	4,899	17,585	26,623
NE	0	283	1,218	5,213	9,295	12,435	28,443
ENE	0	25	6,783	5,150	8,039	44,590	64,586
E	0	0	3,203	11,430	6,029	9,672	30,334
ESE	0	0	5,778	4,899	4,208	4,333	19,218
SE	0	0	452	7,285	5,652	9,797	23,187
SSE	0	0	766	1,143	565	5,087	7,561
S	0	0	1,080	1,570	7,034	3,957	13,641
SSW	0	0	264	2,387	6,908	3,454	13,013
SW	0	0	553	3,894	2,261	3,140	9,847
WSW	0	0	496	5,652	1,821	7,662	15,632
W	0	440	2,575	9,420	3,705	12,435	28,575
WNW	0	4,019	5,778	247,443	84,156	15,701	357,096
NW	0	1,118	15,701	64,059	5,778	2,512	89,167
NNW	0	4,208	40,822	16,957	14,445	4,899	81,330
Total ^b	0	11,670	92,176	396,863	173,336	177,983	852,027
MILK PRODUCTION (liters/yr)							
N	0	1.64 x 10 ⁴	1.03 x 10 ⁵	1.72 x 10 ⁵	1.41 x 10 ⁶	5.57 x 10 ⁶	7.28 x 10 ⁶
NNE	0	1.31 x 10 ⁴	1.03 x 10 ⁵	1.72 x 10 ⁵	3.68 x 10 ⁵	6.06 x 10 ⁵	1.26 x 10 ⁶
NE	0	5.73 x 10 ³	1.22 x 10 ⁵	1.33 x 10 ⁶	2.15 x 10 ⁶	1.39 x 10 ⁶	4.99 x 10 ⁶
ENE	0	1.58 x 10 ³	1.80 x 10 ⁵	1.92 x 10 ⁶	4.82 x 10 ⁶	5.46 x 10 ⁶	1.24 x 10 ⁷
E	0	1.85 x 10 ³	1.80 x 10 ⁵	1.74 x 10 ⁶	4.15 x 10 ⁶	5.76 x 10 ⁶	1.18 x 10 ⁷
ESE	0	4.51 x 10 ¹	1.80 x 10 ⁵	9.31 x 10 ⁵	2.84 x 10 ⁶	1.46 x 10 ⁶	5.41 x 10 ⁶
SE	0	---	1.21 x 10 ⁵	4.52 x 10 ⁴	1.80 x 10 ⁵	4.00 x 10 ⁵	7.46 x 10 ⁵
SSE	0	---	9.38 x 10 ⁴	2.41 x 10 ⁵	3.52 x 10 ⁵	5.64 x 10 ⁵	1.25 x 10 ⁶
S	0	---	3.31 x 10 ⁵	5.74 x 10 ⁵	7.70 x 10 ⁵	9.97 x 10 ⁵	2.67 x 10 ⁶
SSW	0	---	3.58 x 10 ⁵	1.89 x 10 ⁶	6.40 x 10 ⁶	7.61 x 10 ⁶	1.63 x 10 ⁷
SW	0	7.65 x 10 ³	3.87 x 10 ⁵	6.71 x 10 ⁵	3.07 x 10 ⁶	2.84 x 10 ⁶	6.97 x 10 ⁶
WSW	0	2.47 x 10 ³	3.53 x 10 ⁵	6.68 x 10 ⁵	1.05 x 10 ⁶	2.40 x 10 ⁶	4.47 x 10 ⁶
W	0	1.16 x 10 ⁴	1.81 x 10 ⁵	3.79 x 10 ⁵	1.01 x 10 ⁶	1.77 x 10 ⁶	3.36 x 10 ⁶
WNW	0	1.38 x 10 ⁴	1.79 x 10 ⁵	3.46 x 10 ⁵	6.13 x 10 ⁵	8.55 x 10 ⁵	2.01 x 10 ⁶
NW	0	1.75 x 10 ⁴	1.03 x 10 ⁵	4.24 x 10 ⁵	1.16 x 10 ⁶	7.81 x 10 ⁵	2.49 x 10 ⁶
NNW	0	1.79 x 10 ⁴	1.03 x 10 ⁵	2.95 x 10 ⁵	1.48 x 10 ⁶	3.14 x 10 ⁶	5.04 x 10 ⁶
Total ^b	0	1.10 x 10 ⁵	3.08 x 10 ⁶	1.18 x 10 ⁷	3.18 x 10 ⁷	4.16 x 10 ⁷	8.84 x 10 ⁷

Table G-4. Population and Annual Food Production Within 80 Kilometers of the SRP Center^a (continued)

		Distance (km)					
Direction	0-8	8-16	16-32	32-48	48-64	64-80	0-80
MEAT PRODUCTION (kg/yr)							
N	0	8.32×10^4	5.24×10^5	8.73×10^5	1.41×10^6	3.15×10^6	6.05×10^6
NNE	0	6.63×10^4	5.24×10^5	8.73×10^5	2.29×10^6	4.06×10^6	7.81×10^6
NE	0	2.37×10^4	4.71×10^5	7.80×10^5	1.71×10^6	3.01×10^6	5.99×10^6
ENE	0	2.65×10^3	3.02×10^5	5.50×10^5	8.87×10^5	1.06×10^6	2.80×10^6
E	0	3.10×10^3	3.02×10^5	4.74×10^5	6.89×10^5	1.03×10^6	2.50×10^6
ESE	0	7.56×10^1	3.02×10^5	4.66×10^5	6.14×10^5	7.10×10^5	2.09×10^6
SE	0	--	2.74×10^5	3.82×10^5	6.56×10^5	1.00×10^6	2.31×10^6
SSE	0	--	2.35×10^5	4.35×10^5	6.19×10^5	9.88×10^5	2.28×10^6
S	0	--	1.75×10^5	4.58×10^5	7.32×10^5	1.02×10^6	2.39×10^6
SSW	0	--	1.57×10^5	3.93×10^5	1.13×10^6	1.58×10^6	3.26×10^6
SW	0	2.29×10^3	1.33×10^5	2.01×10^5	5.76×10^5	7.57×10^5	1.67×10^6
WSW	0	1.06×10^4	1.75×10^5	2.00×10^5	3.09×10^5	6.65×10^5	1.36×10^6
W	0	5.90×10^4	1.66×10^5	1.19×10^5	2.91×10^5	5.11×10^5	1.15×10^6
WNW	0	7.01×10^4	1.75×10^5	1.09×10^5	1.76×10^5	2.45×10^5	7.75×10^5
NW	0	8.86×10^4	5.24×10^5	6.98×10^5	5.83×10^5	7.01×10^5	2.60×10^6
NNW	0	9.11×10^4	5.24×10^5	8.20×10^5	7.14×10^5	1.45×10^6	3.60×10^6
Total ^b	0	5.01×10^5	4.96×10^6	7.83×10^6	1.34×10^7	2.20×10^7	4.86×10^7
VEGETABLE PRODUCTION (kg/yr)							
N	0	7.39×10^4	4.65×10^5	7.75×10^5	2.16×10^6	3.11×10^6	6.58×10^6
NNE	0	5.89×10^4	4.65×10^5	7.75×10^5	1.18×10^6	1.61×10^6	4.09×10^6
NE	0	4.13×10^4	9.71×10^5	1.08×10^6	1.59×10^6	1.93×10^6	5.61×10^6
ENE	0	2.25×10^4	2.57×10^6	2.89×10^6	2.21×10^6	2.78×10^6	1.05×10^7
E	0	2.64×10^4	2.57×10^6	3.01×10^6	2.72×10^6	3.03×10^6	1.14×10^7
ESE	0	6.44×10^2	2.57×10^6	3.82×10^6	3.44×10^6	9.66×10^5	1.08×10^7
SE	0	--	2.73×10^6	4.97×10^6	4.70×10^6	2.89×10^6	1.53×10^7
SSE	0	--	2.65×10^6	3.71×10^6	5.01×10^6	3.16×10^6	1.45×10^7
S	0	--	1.36×10^6	1.69×10^6	2.50×10^6	3.27×10^6	8.82×10^6
SSW	0	--	1.15×10^6	1.33×10^6	1.86×10^6	2.55×10^6	6.89×10^6
SW	0	1.51×10^4	9.20×10^5	1.33×10^6	1.81×10^6	1.97×10^6	6.04×10^6
WSW	0	1.01×10^4	7.21×10^5	1.31×10^6	1.86×10^6	2.41×10^6	6.31×10^6
W	0	5.23×10^4	1.86×10^5	3.17×10^5	1.18×10^6	2.77×10^6	4.51×10^6
WNW	0	6.22×10^4	1.94×10^5	1.70×10^5	4.89×10^4	1.36×10^6	1.83×10^6
NW	0	7.86×10^4	4.65×10^5	1.59×10^6	4.20×10^6	2.27×10^6	8.59×10^6
NNW	0	8.08×10^4	4.65×10^5	1.25×10^6	5.70×10^6	6.38×10^6	1.39×10^7
Total ^b	0	5.23×10^5	2.05×10^7	3.00×10^7	4.22×10^7	4.24×10^7	1.36×10^8

a. Adapted from Du Pont, 1981, 1982.

b. Reflects rounding.

given in Chapter 4 for each of the cooling alternatives. For facilities on or within 80 kilometers of SRP, the source terms were taken from supporting documentation referenced in Section G.3.

To calculate collective doses to the regional population within 80 kilometers, compass-sector average values of χ/Q and D/Q are used. All atmospheric releases are assumed to occur at the center of the site; the population and agricultural production distributions were centered at the same points. These are reasonable assumptions, given the absence of high population densities near the release points. Collective doses for each year of operation were calculated as the sum of the doses received during that year of operation, plus residual doses for the next 100 years from radioactivity released during that same year. The calculated collective dose is referred to as a 100-year environmental dose commitment (EDC) per year of operation. (The EDC concept is discussed later in this appendix.) The collective dose received by the exposed offsite population is calculated by adding the individual dose commitments in the population. Parameters used in calculating the collective dose to the 80-kilometer radius population are summarized in Table G-5.

The maximally exposed individual is assumed to reside continuously at the location on the Plant boundary with the highest potential exposure. This is true for both current operating conditions and operations associated with the implementation of cooling alternatives. For the latter, the reference release points of radioactivity to the atmosphere are at the midpoint between the two cooling alternative locations selected for each reactor (K and C). The shortest distance from each of the reference release points to the Plant boundary was calculated for each of the 16 cardinal directions. This method was used to determine the highest boundary χ/Q value, thus identifying the location at which a member of the public would receive the highest dose.

All individual doses are 50-year dose commitments. Parameters used in calculating doses to maximally exposed individuals are summarized in Table G-6.

The following exposure pathways were considered for the atmospheric dose assessment:

1. Plume - External dose from radioactive materials transported through the atmosphere
2. Ground - External dose from radioactive materials deposited on the ground
3. Inhalation - Internal dose from inhalation of radioactive materials transported through the atmosphere
4. Vegetation - Internal dose from consumption of crops that have been contaminated by radioactive deposits from the atmosphere
5. Milk - Internal dose from consumption of milk from cows that consume vegetation contaminated by radioactive deposits from the atmosphere
6. Meat - Internal dose from consumption of meat products from beef cattle that consume vegetation contaminated by radioactive deposits from the atmosphere

Table G-5. Parameters and Demographic Data Used in Calculating Collective Dose to the 80-Kilometer Population

Average individual parameters ^a	Child	Teen	Adult
Inhalation (m ³ /yr)	3700	8000	8000
Ingestion ^b			
Cow's milk (liter/yr)	170	200	110
Meat (kg/yr)	37	59	95
Leafy vegetables (kg/yr) ^c	10	20	30
Fruits, vegetables, and grains (kg/yr)	200	240	190
External exposure			
Transmission factor for shielding by residential structures	0.5	0.5	0.5
Demographic data, CY 2000 ^d			
80-kilometer residential population (852,000) age-group distribution	20.8	11.8	67.4

- a. Data are recommended values from Regulatory Guide 1.109 (NRC, 1977).
- b. Foodstuff obtained at large from the 80-kilometer agricultural production of man's foods; any insufficiency is assumed to be imported (uncontaminated). Crop yield and animal feeding data for the 80-kilometer vicinity are presented in Du Pont (1981).
- c. Data from Eckerman et al. (1980).
- d. 1970 census data projected to the assumed midpoint of operations.

The dose to the maximally exposed individual and collective doses to the population within 80 kilometers of SRP from atmospheric radioactive releases from once-through and recirculating cooling towers for K- and C-Reactors are presented in Tables G-7 through G-14. Section G.3 discusses doses from facilities on or within 80 kilometers of the Plant.

G.2 LIQUID RELEASES

The LADTAP II computer code (Simpson and McGill, 1980) was used to calculate radiation exposures due to liquid releases; LADTAP II implements the dose models recommended in NRC Regulatory Guide 1.109, Revision 1 (NRC, 1977). Both maximum-individual and collective doses were calculated as functions of age group and pathway for various body organs. An effective whole-body dose was also calculated.

During operation of the reactors and associated facilities at SRP (existing operations), liquids are released that ultimately discharge into the Savannah River. Included in these releases are radionuclides from reactors and support facilities, and from remobilization from stream beds. The primary radionuclides remobilized is cesium-137 (DOE, 1984b). (Refer to Appendix D.)

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Table G-6. Parameters Used in Calculating Dose to Maximally Exposed Individuals^a

Parameter	Infant	Child	Teen	Adult
Inhalation (m ³ /yr)	1400	3700	8000	8000
Ingestion ^b				
Cow's milk (liter/yr)	330	330	400	310
Meat (kg/yr)	0	41	65	110
Leafy vegetables (kg/yr) ^c	0	26	42	64
Fruits, vegetables, and grains (kg/yr) ^d	0	520	630	520
External exposure				
Transmission factor for shielding from buildings	0.7	0.7	0.7	0.7

- a. Data are recommended values from Regulatory Guide 1.109 (NRC, 1977).
- b. Foodstuff produced at the reference family's location, except as noted, where exposure to the air-released radionuclides is at a maximum. Crop yield and animal feeding parameters are presented in Du Pont (1981).
- c. Seventy-five percent taken from reference family's garden (March-November growing season); remainder imported (uncontaminated).
- d. Seventy-six percent taken from reference family's crops (Regulatory Guide 1.109 recommended value) (NRC, 1977); remainder imported (uncontaminated).

The routine operation of cooling water systems for K- and C-Reactors would result in either no change or a decrease in the remobilization of radionuclides to the Savannah River. This is because flow rates in Four Mile Creek and Indian Grave/Pen Branch would remain essentially unchanged if once-through cooling towers were implemented, and would decrease if recirculating cooling towers were implemented. The routine operation of the cooling water alternative systems for D-Area would produce an insignificant increase in remobilization of radionuclides from Beaver Dam Creek because the creek bed contains insignificant amounts of radionuclides.

The following exposure pathways were considered in the liquid-dose assessments:

1. Drinking water - Internal dose from consumption of drinking water from the Savannah River containing radioactive materials transported by the river
2. Sport and commercial fish - Internal dose from consumption of fish from the Savannah River

Table G-7. Increase in Annual Dose to Maximally Exposed Individual from Increased Release of Tritium to the Atmosphere, Millirem per Year (Once-Through Cooling Tower for K-Reactor)

Pathway	All soft tissues	Effective whole body
ADULT		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	5.28×10^{-5}	4.49×10^{-5}
Meat ingestion	7.86×10^{-6}	6.68×10^{-6}
Milk ingestion	1.85×10^{-5}	1.57×10^{-5}
Inhalation	4.43×10^{-5}	3.77×10^{-5}
Total	1.23×10^{-4}	1.05×10^{-4}
TEEN		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	6.08×10^{-5}	5.17×10^{-5}
Meat ingestion	4.65×10^{-6}	3.95×10^{-6}
Milk ingestion	2.38×10^{-5}	2.02×10^{-5}
Inhalation	4.43×10^{-5}	3.77×10^{-5}
Total	1.34×10^{-4}	1.14×10^{-4}
CHILD		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	4.94×10^{-5}	4.20×10^{-5}
Meat ingestion	2.93×10^{-6}	2.49×10^{-6}
Milk ingestion	1.97×10^{-5}	1.67×10^{-5}
Inhalation	2.04×10^{-5}	1.74×10^{-5}
Total	9.24×10^{-5}	7.86×10^{-5}
INFANT		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	0.0	0.0
Meat ingestion	0.0	0.0
Milk ingestion	1.97×10^{-5}	1.67×10^{-5}
Inhalation	7.74×10^{-6}	6.59×10^{-6}
Total	2.74×10^{-5}	2.33×10^{-5}

Table G-8. Increase in Annual Dose to Maximally Exposed Individual from Increased Release of Tritium to the Atmosphere, Millirem per Year (Once-Through Cooling Tower for C-Reactor)

Pathway	All soft tissues	Effective whole body
ADULT		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	5.44×10^{-5}	4.62×10^{-5}
Meat ingestion	8.10×10^{-6}	6.89×10^{-6}
Milk ingestion	1.90×10^{-5}	1.62×10^{-5}
Inhalation	4.56×10^{-5}	3.87×10^{-5}
Total	1.27×10^{-4}	1.08×10^{-4}
TEEN		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	6.26×10^{-5}	5.32×10^{-5}
Meat ingestion	4.78×10^{-6}	4.06×10^{-6}
Milk ingestion	2.45×10^{-5}	2.08×10^{-5}
Inhalation	4.56×10^{-5}	3.87×10^{-5}
Total	1.37×10^{-4}	1.17×10^{-4}
CHILD		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	5.09×10^{-5}	4.33×10^{-5}
Meat ingestion	3.02×10^{-6}	2.57×10^{-6}
Milk ingestion	2.02×10^{-5}	1.72×10^{-5}
Inhalation	2.10×10^{-5}	1.79×10^{-5}
Total	9.51×10^{-5}	8.09×10^{-5}
INFANT		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	0.0	0.0
Meat ingestion	0.0	0.0
Milk ingestion	2.02×10^{-5}	1.72×10^{-5}
Inhalation	7.97×10^{-6}	6.77×10^{-6}
Total	2.82×10^{-5}	2.40×10^{-5}

Table G-9. Increase in Annual Dose to Maximally Exposed Individual from Increased Release of Tritium to the Atmosphere, Millirem per Year (Recirculating Cooling Towers for K-Reactor)

Pathway	All soft tissues	Effective whole body
ADULT		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	4.48×10^{-4}	3.80×10^{-4}
Meat ingestion	6.68×10^{-5}	5.67×10^{-5}
Milk ingestion	1.57×10^{-4}	1.33×10^{-4}
Inhalation	3.77×10^{-4}	3.21×10^{-4}
Total	1.05×10^{-3}	8.92×10^{-4}
TEEN		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	5.15×10^{-4}	4.39×10^{-4}
Meat ingestion	3.93×10^{-5}	3.35×10^{-5}
Milk ingestion	2.02×10^{-4}	1.72×10^{-4}
Inhalation	3.77×10^{-4}	3.21×10^{-4}
Total	1.13×10^{-3}	9.65×10^{-4}
CHILD		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	4.20×10^{-4}	3.58×10^{-4}
Meat ingestion	2.48×10^{-5}	2.11×10^{-5}
Milk ingestion	1.67×10^{-4}	1.42×10^{-4}
Inhalation	1.74×10^{-4}	1.48×10^{-4}
Total	7.87×10^{-4}	6.69×10^{-4}
INFANT		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	0.0	0.0
Meat ingestion	0.0	0.0
Milk ingestion	1.67×10^{-4}	1.42×10^{-4}
Inhalation	6.56×10^{-5}	5.57×10^{-5}
Total	2.32×10^{-4}	1.98×10^{-4}

Table G-10. Increase in Annual Dose to Maximally Exposed Individual from Increased Release of Tritium to the Atmosphere, Millirem per Year (Recirculating Cooling Towers for C-Reactor)

Pathway	All soft tissues	Effective whole body
ADULT		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	4.62×10^{-4}	3.93×10^{-4}
Meat ingestion	6.88×10^{-5}	5.84×10^{-5}
Milk ingestion	1.62×10^{-4}	1.37×10^{-4}
Inhalation	3.86×10^{-4}	3.27×10^{-4}
Total	1.08×10^{-3}	9.15×10^{-4}
TEEN		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	5.33×10^{-4}	4.51×10^{-4}
Meat ingestion	4.06×10^{-5}	3.46×10^{-5}
Milk ingestion	2.09×10^{-4}	1.78×10^{-4}
Inhalation	3.86×10^{-4}	3.27×10^{-4}
Total	1.17×10^{-3}	9.91×10^{-4}
CHILD		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	4.33×10^{-4}	3.68×10^{-4}
Meat ingestion	2.57×10^{-5}	2.17×10^{-5}
Milk ingestion	1.72×10^{-4}	1.46×10^{-4}
Inhalation	1.79×10^{-4}	1.52×10^{-4}
Total	8.09×10^{-4}	6.87×10^{-4}
INFANT		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	0.0	0.0
Meat ingestion	0.0	0.0
Milk ingestion	1.72×10^{-4}	1.46×10^{-4}
Inhalation	6.77×10^{-5}	5.75×10^{-5}
Total	2.40×10^{-4}	2.03×10^{-4}

Table G-11. Increase in 80-Kilometer Collective Dose from Increased Release of Tritium to the Atmosphere, Person-Rem per Year (Once-Through Cooling Tower for K-Reactor)

Pathway	All soft tissues	Effective whole body
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	1.59×10^{-3}	1.35×10^{-3}
Meat ingestion	3.03×10^{-4}	2.58×10^{-4}
Milk ingestion	3.85×10^{-4}	3.27×10^{-4}
Inhalation	3.57×10^{-3}	3.03×10^{-3}
Total	5.85×10^{-3}	4.97×10^{-3}

Table G-12. Increase in 80-Kilometer Collective Dose from Increased Release of Tritium to the Atmosphere, Person-Rem per Year (Once-Through Cooling Tower for C-Reactor)

Pathway	All soft tissues	Effective whole body
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	1.59×10^{-3}	1.35×10^{-3}
Meat ingestion	3.03×10^{-4}	2.58×10^{-4}
Milk ingestion	3.85×10^{-4}	3.27×10^{-4}
Inhalation	3.57×10^{-3}	3.03×10^{-3}
Total	5.85×10^{-3}	4.97×10^{-3}

3. Salt-water invertebrates - Internal dose from consumption of shellfish from estuaries of the Savannah River
4. Recreation - External dose from recreational activities on or along the Savannah River shoreline

All individual and collective doses were based on the assumption that liquids discharged are mixed completely in the river before reaching the potential exposure pathways. This assumption is supported by measurements that indicate complete mixing of the liquids before they reach the Highway 301 bridge. A dilution factor of 3 was applied to the shellfish dose calculation because a significant portion of the harvest would be from estuarine or ocean waters.

Individual and site parameters used in the calculations are summarized in Tables G-15 and G-16. The data on fish consumption are based on data from the region.

Table G-13. Increase in 80-Kilometer Collective Dose from Increased Release of Tritium to the Atmosphere, Person-Rem per Year (Recirculating Cooling Towers for K-Reactor)

Pathway	All soft tissues	Effective whole body
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	1.35×10^{-2}	1.15×10^{-2}
Meat ingestion	2.57×10^{-3}	2.18×10^{-3}
Milk ingestion	3.28×10^{-3}	2.78×10^{-3}
Inhalation	3.03×10^{-2}	2.59×10^{-2}
Total	4.98×10^{-2}	4.22×10^{-2}

Table G-14. Increase in 80-Kilometer Collective Dose from Increased Release of Tritium to the Atmosphere, Person-Rem per Year (Recirculating Cooling Towers for C-Reactor)

Pathway	All soft tissues	Effective whole body
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	1.35×10^{-2}	1.15×10^{-2}
Meat ingestion	2.57×10^{-3}	2.18×10^{-3}
Milk ingestion	3.28×10^{-3}	2.78×10^{-3}
Inhalation	3.03×10^{-2}	2.59×10^{-2}
Total	4.98×10^{-2}	4.22×10^{-2}

TE | The individual who would receive the maximum potential dose from liquid releases is assumed to live near the Savannah River downstream from SRP. It is assumed this individual uses river water regularly for drinking, consumes river fish, and receives external exposure from shoreline activities.

TE | The collective doses received by the offsite population as a result of liquid releases is estimated by summing the doses to the individuals in the population. The population within an 80-kilometer radius uses no river water for domestic purposes downstream from SRP. It is assumed this population uses the river for recreational purposes and consumes fish and shellfish from the river and its estuary.

There is no known human consumption of Savannah River water up to a distance of about 160 kilometers downstream from SRP. At this distance, Beaufort and Jasper Counties, South Carolina, will pump water from the river for treatment

Table G-15. Individual Parameters Used in Dose Calculations

Parameters	Child	Teen	Adult
AVERAGE INDIVIDUAL ^a			
Water consumption (liter/year)	260	260	370
Fish consumption (kg/yr)	3.6	8.5	11.3
Other seafood consumption (kg/yr)	0.33	0.75	1.0
Shoreline recreation (hr/yr)	9.5	47	8.3
Shoreline recreation (person-hours)	--	--	200,000
MAXIMUM INDIVIDUAL			
Water consumption (liter/yr) ^b	510	510	730
Fish consumption (kg/yr)	11.2	25.9	34
Other seafood consumption (kg/yr)	1.7	3.8	5
Shoreline recreation (hr/yr)	14	67	20

a. For collective dose calculations.

b. Drinking-water consumption for an infant equals 330 liters per year.

Table G-16. Site Parameters Used in Dose Calculations

Parameters	Values
River flow rate (m ³ /s)	
Average (m ³ /s)	294
Low flow (m ³ /s)	173
River dilution in estuary	3
Transit time to river (hr)	24
Transit time, SRP to water-treatment plants (hr)	72
Water-treatment time (hr)	24
Aquatic food harvest (kg/yr)	
Fish--sport	90,700
Fish--commercial	31,800
Invertebrates--salt water	299,000
Irrigation	None
Shore-width factor	0.2
Population in year 2000 ^a	
Beaufort-Jasper water consumers	117,000
Port Wentworth water consumers	200,000
80-kilometer-radius population	852,000

a. Age distribution of population: Beaufort-Jasper--21 percent child, 10 percent teen, 69 percent adult; Port Wentworth--100 percent adult; 80-kilometer radius--21 percent child, 11 percent teen, 68 percent adult.

and service to about 117,000 people in the year 2000. Several kilometers farther downstream, the Cherokee Hill water-treatment plant draws water from the river to supply a business-industrial complex near Savannah, Georgia. This water is not used for normal domestic service, but it is assumed that about 200,000 people will use this water during the year 2000 (DOE, 1984a). Although these population groups are beyond the 80-kilometer radius, collective doses from drinking-water for these groups have been included in this document. All population doses are 100-year environmental dose commitments.

The doses to the maximally exposed individual and collective dose from liquid radioactive releases from once-through and recirculating cooling-towers for K- and C-Reactors are presented in Tables G-17 through G-28. Section G.3 discusses doses from facilities on or within 80 kilometers of SRP.

G.3 CUMULATIVE EFFECTS

The evaluation of the radiological impacts associated with the implementation of the alternative cooling water systems has also considered the cumulative effects of the operation of all other nuclear facilities in the affected region. This region includes SRP and the area within 80 kilometers of the Plant. These cumulative effects are summarized in Section 4.4.

Impacts for the following nuclear facilities, which represent existing and planned operations, have been considered in the calculation of cumulative effects:

- Four onsite production reactors (L, P, K, and C) using current cooling water systems, and associated support facilities
- The Defense Waste Processing Facility (DWPF) under construction at S-Area on the Plant
- The Fuel Materials Facility (FMF) under construction at F-Area on the Plant
- The Fuel Production Facility (FPF) to be constructed at H-Area on the Plant
- The Vogtle Electric Generating Station (VEGS) under construction across the Savannah River from the southwestern boundary of the site

The maximum individual and collective doses associated with each of these facilities are presented in Tables G-29, G-30, G-31, and G-32. These represent basecase doses. Information necessary for these dose calculations was derived from supporting environmental documentation available for each facility (DOE, 1982a,b; 1984a; Du Pont, 1983; Georgia Power Company, 1985).

To obtain the cumulative impact of the operation of nuclear facilities in the region, including the alternative cooling water systems, the changes in doses associated with operation of the cooling water systems (Tables G-7 through

Table G-17. Decrease in Annual Dose to Maximally Exposed Individual from Reduced Release of Tritium to Indian Grave/Pen Branch, Millirem per Year (Once-Through Cooling Tower for K-Reactor)

Pathway	All soft tissues	Effective whole body
ADULT		
Fish	1.04×10^{-5}	8.84×10^{-6}
Drinking	2.47×10^{-4}	2.10×10^{-4}
Total	2.58×10^{-4}	2.19×10^{-4}
TEEN		
Fish	7.90×10^{-6}	6.72×10^{-6}
Drinking	1.73×10^{-4}	1.47×10^{-4}
Total	1.81×10^{-4}	1.54×10^{-4}
CHILD		
Fish	3.42×10^{-6}	2.91×10^{-6}
Drinking	1.73×10^{-4}	1.47×10^{-4}
Total	1.76×10^{-4}	1.50×10^{-4}
INFANT		
Drinking	1.12×10^{-4}	9.52×10^{-5}
Total	1.12×10^{-4}	9.52×10^{-5}

G-14 and G-17 through G-28) must be combined with the existing doses. These cumulative doses are presented in Tables G-33 through G-38.

G.4 ENVIRONMENTAL DOSE COMMITMENT CONCEPT

Man can receive doses externally from radioactive materials outside the body or internally from the intake of radioactive material by inhalation or ingestion. Radionuclides that enter the body are distributed to various organs and are removed by normal biological processes and radioactive decay. The rate at which each radionuclide is removed from the body depends on its chemical, physical, and radiological properties. Historically, dose calculations have included an accounting of doses resulting from the fraction of radionuclides retained in the body for 50 years following the year of intake. This 50-year integrating period is included in the dose-commitment factors used in these dose calculations.

Table G-18. Decrease in Annual Dose to Maximally Exposed Individual from Reduced Release of Tritium to Four Mile Creek, Millirem per Year (Once-Through Cooling Tower for C-Reactor)

Pathway	All soft tissues	Effective whole body
ADULT		
Fish	1.04×10^{-5}	8.84×10^{-6}
Drinking	2.47×10^{-4}	2.10×10^{-4}
Total	2.58×10^{-4}	2.19×10^{-4}
TEEN		
Fish	7.90×10^{-6}	6.72×10^{-6}
Drinking	1.73×10^{-4}	1.47×10^{-4}
Total	1.81×10^{-4}	1.54×10^{-4}
CHILD		
Fish	3.42×10^{-6}	2.91×10^{-6}
Drinking	1.73×10^{-4}	1.47×10^{-4}
Total	1.76×10^{-4}	1.50×10^{-4}
INFANT		
Drinking	1.12×10^{-4}	9.52×10^{-5}
Total	1.12×10^{-4}	9.52×10^{-5}

Similarly, radioactive material released in any year remains in the environment for varying lengths of time, depending on many environmental factors and on the decay rate of each radionuclide. The environmental-dose-commitment (EDC) concept is employed to account for this residual activity.

The EDC concept has been developed by the U.S. Environmental Protection Agency (EPA, 1974). EPA has defined the environmental dose commitment as "the sum of all doses to individuals over the entire time period the material persists in the environment in a state available for interaction with humans." The EPA report describes how this concept is implemented and presents some sample calculations. These calculations integrate doses for 100 years following radionuclide release rather than "the entire time period." This 100-year integrating period is distinct from the 50-year integrating period discussed above because it deals with the accumulation of doses from residual radioactivity in the environment rather than in the body.

Table G-19. Decrease in Annual Dose to Maximally Exposed Individual from Reduced Release of Tritium to Indian Grave/Pen Branch, Millirem per Year (Recirculating Cooling Towers for K-Reactor)

Pathway	All soft tissues	Effective whole body
ADULT		
Fish	8.81×10^{-5}	7.48×10^{-5}
Drinking	2.09×10^{-3}	1.78×10^{-3}
Total	2.18×10^{-3}	1.85×10^{-3}
TEEN		
Fish	6.72×10^{-5}	5.70×10^{-5}
Drinking	1.47×10^{-3}	1.25×10^{-3}
Total	1.53×10^{-3}	1.31×10^{-3}
CHILD		
Fish	2.90×10^{-5}	2.47×10^{-5}
Drinking	1.47×10^{-3}	1.25×10^{-3}
Total	1.50×10^{-3}	1.27×10^{-3}
INFANT		
Drinking	9.48×10^{-4}	8.06×10^{-4}
Total	9.48×10^{-4}	8.06×10^{-4}

This analysis uses the 100-year integrating period. All collective dose calculations include an accounting of collective dose resulting from environmental radioactivity levels for 100 years following each year's release. The 100-year period provides meaningful results by accounting for impacts over a period of time about equal to the maximum lifetime of an individual; thus, it provides a measure of risk to an individual. Longer integrating periods or an infinite time integral would require extremely speculative predictions.

For all EDC calculations, no attempt was made to predict changes in environmental characteristics. Population size and distribution were based on estimates for the year 2000. Historical meteorological patterns and conditions were assumed to continue, and food production and consumption patterns were assumed to be static.

Table G-20. Decrease in Annual Dose to Maximally Exposed Individual from Reduced Release of Tritium to Four Mile Creek, Millirem per Year (Recirculating Cooling Towers for C-Reactor)

Pathway	All soft tissues	Effective whole body
ADULT		
Fish	8.81×10^{-5}	7.48×10^{-5}
Drinking	2.09×10^{-3}	1.78×10^{-3}
Total	2.18×10^{-3}	1.85×10^{-3}
TEEN		
Fish	6.72×10^{-5}	5.70×10^{-5}
Drinking	1.47×10^{-3}	1.25×10^{-3}
Total	1.53×10^{-3}	1.31×10^{-3}
CHILD		
Fish	2.90×10^{-5}	2.47×10^{-5}
Drinking	1.47×10^{-3}	1.25×10^{-3}
Total	1.50×10^{-3}	1.27×10^{-3}
INFANT		
Drinking	9.48×10^{-4}	8.06×10^{-4}
Total	9.48×10^{-4}	8.06×10^{-4}

G.5 RADIATION-INDUCED HEALTH EFFECTS

Radiation can affect human health by causing cancer, genetic disorders, and other health problems. The Committee on the Biological Effects of Ionizing Radiation (BEIR) of the National Academy of Sciences has published a detailed review of available data on radiation-induced health effects (BEIR, 1980). This report (BEIR III) uses a variety of methods and data to quantify the health impacts of low levels of radiation. Its estimates of health risk associated with radiation exposure have been used to quantify the possible changes in radiation-induced health effects that might be caused by operation of the cooling water systems. These potential health effects are discussed in Chapter 4.

The International Commission on Radiological Protection provides risk estimates for radiation exposure in ICRP Publication 26 (ICRP, 1977). These risk estimates for cancer mortality are generally consistent with BEIR III.

Table G-21. Decrease in Annual Dose to Maximally Exposed Individual from Reduced Remobilization of Radiocesium from Indian Grave/Pen Branch Stream Bed, Millirem per Year (Recirculating Cooling Towers for K-Reactor)

Pathway	Gonads	Breast	R. Marrow	Lung	Thyroid	Bone Surface	SI Wall	ULI Wall	LLI Wall	Effective whole body
ADULT										
Fish	6.82×10^{-2}	5.85×10^{-2}	6.33×10^{-2}	6.33×10^{-2}	6.33×10^{-2}	6.33×10^{-2}	6.82×10^{-2}	6.82×10^{-2}	6.82×10^{-2}	6.82×10^{-2}
Drinking	4.88×10^{-4}	4.18×10^{-4}	4.53×10^{-4}	4.53×10^{-4}	4.53×10^{-4}	4.53×10^{-4}	4.88×10^{-4}	4.88×10^{-4}	4.88×10^{-4}	4.88×10^{-4}
Shoreline	1.26×10^{-4}	1.14×10^{-4}	9.56×10^{-5}	9.42×10^{-5}	1.18×10^{-4}	1.07×10^{-4}	7.84×10^{-5}	9.22×10^{-5}	8.53×10^{-5}	1.06×10^{-4}
Total	6.88×10^{-2}	5.90×10^{-2}	6.38×10^{-2}	6.38×10^{-2}	6.39×10^{-2}	6.39×10^{-2}	6.88×10^{-2}	6.88×10^{-2}	6.88×10^{-2}	6.88×10^{-2}
TEEN										
Fish	5.20×10^{-2}	4.45×10^{-2}	4.82×10^{-2}	4.82×10^{-2}	4.82×10^{-2}	4.82×10^{-2}	5.20×10^{-2}	5.20×10^{-2}	5.20×10^{-2}	5.20×10^{-2}
Drinking	3.41×10^{-4}	2.92×10^{-4}	3.17×10^{-4}	3.17×10^{-4}	3.17×10^{-4}	3.17×10^{-4}	3.41×10^{-4}	3.41×10^{-4}	3.41×10^{-4}	3.41×10^{-4}
Shoreline	4.22×10^{-4}	3.83×10^{-4}	3.20×10^{-4}	3.16×10^{-4}	3.96×10^{-4}	3.57×10^{-4}	2.63×10^{-4}	3.09×10^{-4}	2.86×10^{-4}	3.55×10^{-4}
Total	5.28×10^{-2}	4.52×10^{-2}	4.88×10^{-2}	4.88×10^{-2}	4.89×10^{-2}	4.89×10^{-2}	5.26×10^{-2}	5.26×10^{-2}	5.26×10^{-2}	5.27×10^{-2}
CHILD										
Fish	2.25×10^{-2}	1.93×10^{-2}	2.09×10^{-2}	2.09×10^{-2}	2.09×10^{-2}	2.09×10^{-2}	2.25×10^{-2}	2.25×10^{-2}	2.25×10^{-2}	2.25×10^{-2}
Drinking	3.41×10^{-4}	2.92×10^{-4}	3.17×10^{-4}	3.17×10^{-4}	3.17×10^{-4}	3.17×10^{-4}	3.41×10^{-4}	3.41×10^{-4}	3.41×10^{-4}	3.41×10^{-4}
Shoreline	8.81×10^{-5}	7.99×10^{-5}	6.69×10^{-5}	6.60×10^{-5}	8.28×10^{-5}	7.46×10^{-5}	5.49×10^{-5}	6.45×10^{-5}	5.97×10^{-5}	7.42×10^{-5}
Total	2.29×10^{-2}	1.97×10^{-2}	2.13×10^{-2}	2.13×10^{-2}	2.13×10^{-2}	2.13×10^{-2}	2.29×10^{-2}	2.29×10^{-2}	2.29×10^{-2}	2.29×10^{-2}
INFANT										
Drinking	2.21×10^{-4}	1.89×10^{-4}	2.05×10^{-4}	2.05×10^{-4}	2.05×10^{-4}	2.05×10^{-4}	2.21×10^{-4}	2.21×10^{-4}	2.21×10^{-4}	2.21×10^{-4}
Total	2.21×10^{-4}	1.89×10^{-4}	2.05×10^{-4}	2.05×10^{-4}	2.05×10^{-4}	2.05×10^{-4}	2.21×10^{-4}	2.21×10^{-4}	2.21×10^{-4}	2.21×10^{-4}

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BC-22

Table G-22. Decrease in Annual Dose to Maximally Exposed Individual from Reduced Remobilization of Radiocesium from Four Mile Creek Stream Bed, Millirem per Year (Recirculating Cooling Towers for C-Reactor)

Pathway	Gonads	Breast	R. Marrow	Lung	Thyroid	Bone Surface	SI Wall	ULI Wall	LLI Wall	Effective whole body
ADULT										
Fish	1.19×10^{-1}	1.02×10^{-1}	1.11×10^{-1}	1.11×10^{-1}	1.11×10^{-1}	1.11×10^{-1}	1.19×10^{-1}	1.19×10^{-1}	1.19×10^{-1}	1.19×10^{-1}
Drinking	8.54×10^{-4}	7.32×10^{-4}	7.93×10^{-4}	7.93×10^{-4}	7.93×10^{-4}	7.93×10^{-4}	8.54×10^{-4}	8.54×10^{-4}	8.54×10^{-4}	8.54×10^{-4}
Shoreline	2.20×10^{-4}	2.00×10^{-4}	1.67×10^{-4}	1.65×10^{-4}	2.07×10^{-4}	1.87×10^{-4}	1.37×10^{-4}	1.61×10^{-4}	1.49×10^{-4}	1.85×10^{-4}
Total	1.20×10^{-1}	1.03×10^{-1}	1.12×10^{-1}	1.12×10^{-1}	1.12×10^{-1}	1.12×10^{-1}	1.20×10^{-1}	1.20×10^{-1}	1.20×10^{-1}	1.20×10^{-1}
TEEN										
Fish	9.09×10^{-2}	7.79×10^{-2}	8.44×10^{-2}	8.44×10^{-2}	8.44×10^{-2}	8.44×10^{-2}	9.09×10^{-2}	9.09×10^{-2}	9.09×10^{-2}	9.09×10^{-2}
Drinking	5.97×10^{-4}	5.12×10^{-4}	5.54×10^{-4}	5.54×10^{-4}	5.54×10^{-4}	5.54×10^{-4}	5.97×10^{-4}	5.97×10^{-4}	5.97×10^{-4}	5.97×10^{-4}
Shoreline	7.38×10^{-4}	6.69×10^{-4}	5.61×10^{-4}	5.53×10^{-4}	6.94×10^{-4}	6.25×10^{-4}	4.60×10^{-4}	5.40×10^{-4}	5.00×10^{-4}	6.21×10^{-4}
Total	9.22×10^{-2}	7.91×10^{-2}	8.55×10^{-2}	8.55×10^{-2}	8.56×10^{-2}	8.56×10^{-2}	9.20×10^{-2}	9.20×10^{-2}	9.20×10^{-2}	9.21×10^{-2}
CHILD										
Fish	3.93×10^{-2}	3.37×10^{-2}	3.65×10^{-2}	3.65×10^{-2}	3.65×10^{-2}	3.65×10^{-2}	3.93×10^{-2}	3.93×10^{-2}	3.93×10^{-2}	3.93×10^{-2}
Drinking	5.97×10^{-4}	5.12×10^{-4}	5.54×10^{-4}	5.54×10^{-4}	5.54×10^{-4}	5.54×10^{-4}	5.97×10^{-4}	5.97×10^{-4}	5.97×10^{-4}	5.97×10^{-4}
Shoreline	1.54×10^{-4}	1.40×10^{-4}	1.17×10^{-4}	1.15×10^{-4}	1.45×10^{-4}	1.31×10^{-4}	9.61×10^{-5}	1.13×10^{-4}	1.04×10^{-4}	1.30×10^{-4}
Total	4.01×10^{-2}	3.44×10^{-2}	3.72×10^{-2}	3.72×10^{-2}	3.72×10^{-2}	3.72×10^{-2}	4.00×10^{-2}	4.00×10^{-2}	4.00×10^{-2}	4.00×10^{-2}
INFANT										
Drinking	3.86×10^{-4}	3.31×10^{-4}	3.59×10^{-4}	3.59×10^{-4}	3.59×10^{-4}	3.59×10^{-4}	3.86×10^{-4}	3.86×10^{-4}	3.86×10^{-4}	3.86×10^{-4}
Total	3.86×10^{-4}	3.31×10^{-4}	3.59×10^{-4}	3.59×10^{-4}	3.59×10^{-4}	3.59×10^{-4}	3.86×10^{-4}	3.86×10^{-4}	3.86×10^{-4}	3.86×10^{-4}

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BC-22

Table G-23. Decrease in Collective Dose from Reduced Tritium Release to Indian Grave/Pen Branch, Person-Rem per Year (Once-Through Cooling Tower for K-Reactor)

Pathway	All soft tissues	Effective whole body
Drinking water		
Beaufort-Jasper	1.33×10^{-2}	1.13×10^{-2}
Port Wentworth	2.51×10^{-2}	2.13×10^{-2}
Total	3.84×10^{-2}	3.26×10^{-2}
Sport fish	2.72×10^{-5}	2.31×10^{-5}
Commercial fish	1.73×10^{-6}	1.47×10^{-6}
Shellfish	5.32×10^{-8}	4.52×10^{-8}
Total	2.90×10^{-5}	2.46×10^{-5}
Grand total	3.84×10^{-2}	3.26×10^{-2}

Table G-24. Decrease in Collective Dose from Reduced Tritium Release to Four Mile Creek, Person-Rem per Year (Once-Through Cooling Tower for C-Reactor)

Pathway	All soft tissues	Effective whole body
Drinking water		
Beaufort-Jasper	1.33×10^{-2}	1.13×10^{-2}
Port Wentworth	2.51×10^{-2}	2.13×10^{-2}
Total	3.84×10^{-2}	3.26×10^{-2}
Sport fish	2.72×10^{-5}	2.31×10^{-5}
Commercial fish	1.73×10^{-6}	1.47×10^{-6}
Shellfish	5.32×10^{-8}	4.52×10^{-8}
Total	2.90×10^{-5}	2.46×10^{-5}
Grand total	3.84×10^{-2}	3.26×10^{-2}

Table G-25. Decrease in Collective Dose from Reduced Tritium Release to Indian Grave/Pen Branch, Person-Rem per Year (Recirculating Cooling Towers for K-Reactor)

Pathway	All soft tissues	Effective whole body
Drinking water		
Beaufort-Jasper	1.13×10^{-1}	9.58×10^{-2}
Port Wentworth	2.14×10^{-1}	1.82×10^{-1}
Total	3.27×10^{-1}	2.78×10^{-1}
Sport fish	2.30×10^{-4}	1.96×10^{-4}
Commercial fish	1.47×10^{-5}	1.25×10^{-5}
Shellfish	4.52×10^{-7}	3.84×10^{-7}
Total	2.45×10^{-4}	2.09×10^{-4}
Grand total	3.27×10^{-1}	2.78×10^{-1}

Table G-26. Decrease in Collective Dose from Reduced Tritium Release to Four Mile Creek, Person-Rem per Year (Recirculating Cooling Towers for C-Reactor)

Pathway	All soft tissues	Effective whole body
Drinking water		
Beaufort-Jasper	1.13×10^{-1}	9.58×10^{-2}
Port Wentworth	2.14×10^{-1}	1.82×10^{-1}
Total	3.27×10^{-1}	2.78×10^{-1}
Sport fish	2.30×10^{-4}	1.96×10^{-4}
Commercial fish	1.47×10^{-5}	1.25×10^{-5}
Shellfish	4.52×10^{-7}	3.84×10^{-7}
Total	2.45×10^{-4}	2.09×10^{-4}
Grand total	3.27×10^{-1}	2.78×10^{-1}

The total cancer risk for all organs reported in ICRP-26 is 1.25×10^{-4} per rem, compared to 1.20×10^{-4} reported in BEIR III. However, the genetic risk estimate reported in ICRP-26 is about three times lower than that of BEIR III. BEIR III risk estimates were used in this analysis because (1) BEIR III is a more recent and comprehensive evaluation of radiation-induced health effects and (2) BEIR III results in higher estimates of total risk.

Table G-27. Decrease in Collective Dose from Reduced Remobilization of Radiocesium from Indian Grave/Pen Branch Stream Bed, Person-Rem Per Year (Recirculating Cooling Towers for K-Reactor)

Pathway	Gonads	Breast	R. Marrow	Lung	Thyroid	Bone Surface	SI Wall	ULI Wall	LLI Wall	Effective whole body
Drinking water										
Beaufort-Jasper	1.05×10^{-2}	8.99×10^{-3}	9.74×10^{-3}	9.74×10^{-3}	9.74×10^{-3}	9.74×10^{-3}	1.05×10^{-2}	1.05×10^{-2}	1.05×10^{-2}	1.05×10^{-2}
Port Wentworth	3.81×10^{-2}	3.27×10^{-2}	3.54×10^{-2}	3.54×10^{-2}	3.54×10^{-2}	3.54×10^{-2}	3.81×10^{-2}	3.81×10^{-2}	3.81×10^{-2}	3.81×10^{-2}
Total	4.86×10^{-2}	4.17×10^{-2}	4.51×10^{-2}	4.51×10^{-2}	4.51×10^{-2}	4.51×10^{-2}	4.86×10^{-2}	4.86×10^{-2}	4.86×10^{-2}	4.86×10^{-2}
Sport fish	1.79×10^{-1}	1.53×10^{-1}	1.66×10^{-1}	1.66×10^{-1}	1.66×10^{-1}	1.66×10^{-1}	1.79×10^{-1}	1.79×10^{-1}	1.79×10^{-1}	1.79×10^{-1}
Commercial fish	1.14×10^{-2}	9.74×10^{-3}	1.06×10^{-2}	1.06×10^{-2}	1.06×10^{-2}	1.06×10^{-2}	1.14×10^{-2}	1.14×10^{-2}	1.14×10^{-2}	1.14×10^{-2}
Shellfish	2.83×10^{-6}	2.42×10^{-6}	2.63×10^{-6}	2.63×10^{-6}	2.63×10^{-6}	2.63×10^{-6}	2.83×10^{-6}	2.83×10^{-6}	2.83×10^{-6}	2.83×10^{-6}
Shoreline	1.26×10^{-3}	1.14×10^{-3}	9.56×10^{-4}	9.42×10^{-4}	1.18×10^{-3}	1.07×10^{-3}	7.84×10^{-4}	9.22×10^{-4}	8.53×10^{-4}	1.06×10^{-3}
Total	1.92×10^{-1}	1.64×10^{-1}	1.78×10^{-1}	1.78×10^{-1}	1.78×10^{-1}	1.78×10^{-1}	1.91×10^{-1}	1.91×10^{-1}	1.91×10^{-1}	1.91×10^{-1}
Grand Total	2.40×10^{-1}	2.06×10^{-1}	2.23×10^{-1}	2.23×10^{-1}	2.23×10^{-1}	2.23×10^{-1}	2.40×10^{-1}	2.40×10^{-1}	2.40×10^{-1}	2.40×10^{-1}

Table G-28. Decrease in Collective Dose from Reduced Remobilization of Radiocesium from Four Mile Creek Stream Bed, Person-Rem Per Year (Recirculating Cooling Towers for C-Reactor)

Pathway	Gonads	Breast	R. Marrow	Lung	Thyroid	Bone Surface	SI Wall	ULI Wall	LLI Wall	Effective whole body
Drinking water										
Beaufort-Jasper	1.83×10^{-2}	1.57×10^{-2}	1.70×10^{-2}	1.70×10^{-2}	1.70×10^{-2}	1.70×10^{-2}	1.83×10^{-2}	1.83×10^{-2}	1.83×10^{-2}	1.83×10^{-2}
Port Wentworth	6.67×10^{-2}	5.71×10^{-2}	6.19×10^{-2}	6.19×10^{-2}	6.19×10^{-2}	6.19×10^{-2}	6.67×10^{-2}	6.67×10^{-2}	6.67×10^{-2}	6.67×10^{-2}
Total	8.50×10^{-2}	7.28×10^{-2}	7.89×10^{-2}	7.89×10^{-2}	7.89×10^{-2}	7.89×10^{-2}	8.50×10^{-2}	8.50×10^{-2}	8.50×10^{-2}	8.50×10^{-2}
Sport fish	3.13×10^{-1}	2.68×10^{-1}	2.91×10^{-1}	2.19×10^{-1}	2.91×10^{-1}	2.91×10^{-1}	3.13×10^{-1}	3.13×10^{-1}	3.13×10^{-1}	3.13×10^{-1}
Commercial fish	1.99×10^{-2}	1.71×10^{-2}	1.85×10^{-2}	1.85×10^{-2}	1.85×10^{-2}	1.85×10^{-2}	1.99×10^{-2}	1.99×10^{-2}	1.99×10^{-2}	1.99×10^{-2}
Shellfish	4.95×10^{-6}	4.24×10^{-6}	4.59×10^{-6}	4.59×10^{-6}	4.59×10^{-6}	4.59×10^{-6}	4.95×10^{-6}	4.95×10^{-6}	4.95×10^{-6}	4.95×10^{-6}
Shoreline	2.20×10^{-3}	2.00×10^{-3}	1.67×10^{-3}	1.65×10^{-3}	2.07×10^{-3}	1.87×10^{-3}	1.37×10^{-3}	1.61×10^{-3}	1.49×10^{-3}	1.85×10^{-3}
Total	3.35×10^{-1}	2.87×10^{-1}	3.11×10^{-1}	3.11×10^{-1}	3.12×10^{-1}	3.11×10^{-1}	3.34×10^{-1}	3.35×10^{-1}	3.34×10^{-1}	3.35×10^{-1}
Grand Total	4.20×10^{-1}	3.60×10^{-1}	3.90×10^{-1}	3.90×10^{-1}	3.90×10^{-1}	3.90×10^{-1}	4.19×10^{-1}	4.20×10^{-1}	4.19×10^{-1}	4.20×10^{-1}

Table G-29. Annual Maximum Individual Doses from Atmospheric Releases; Cumulative Impact Without the Cooling Alternatives, in Year 2000 (Millirem Per Year)

Receptor organ	Facilities					Total from all facilities
	SRP	DWPF	FMF	FPF ^a	Vogtle ^b	
ADULT						
Gonads	5.85 x 10 ⁻¹	1.89 x 10 ⁻⁴	5.41 x 10 ⁻⁷	1.15 x 10 ⁻⁸		5.85 x 10 ⁻¹
Breast	5.99 x 10 ⁻¹	1.68 x 10 ⁻⁴	2.75 x 10 ⁻⁶	2.16 x 10 ⁻⁸		5.99 x 10 ⁻¹
R. Marrow	1.85 x 10 ⁻¹	1.07 x 10 ⁻³	5.93 x 10 ⁻⁵	2.49 x 10 ⁻⁷	5.59 x 10 ⁻¹	7.45 x 10 ⁻¹
Lungs	6.47 x 10 ⁻¹	4.33 x 10 ⁻⁴	4.53 x 10 ⁻²	1.90 x 10 ⁻⁴	3.41 x 10 ⁻¹	1.03
Thyroid	3.77	6.54 x 10 ⁻³	1.77 x 10 ⁻⁷	9.69 x 10 ⁻⁹	9.96 x 10 ⁻¹	4.77
Bone Surface	3.59 x 10 ⁻¹	2.77 x 10 ⁻³	9.19 x 10 ⁻⁴	3.77 x 10 ⁻⁶		3.63 x 10 ⁻¹
ST Wall	4.88 x 10 ⁻¹	7.59 x 10 ⁻⁵	8.53 x 10 ⁻⁸	6.37 x 10 ⁻⁹		4.88 x 10 ⁻¹
SI Wall	4.85 x 10 ⁻¹	1.53 x 10 ⁻⁴	5.58 x 10 ⁻⁸	5.50 x 10 ⁻⁹		4.85 x 10 ⁻¹
ULI Wall	6.20 x 10 ⁻¹	2.72 x 10 ⁻⁴	3.27 x 10 ⁻⁴	7.24 x 10 ⁻⁵		6.21 x 10 ⁻¹
LLI Wall	5.62 x 10 ⁻¹	4.74 x 10 ⁻⁴	1.00 x 10 ⁻³	2.06 x 10 ⁻⁴	3.45 x 10 ⁻¹	9.09 x 10 ⁻¹
Kidneys	4.37 x 10 ⁻¹	7.97 x 10 ⁻⁵	3.88 x 10 ⁻⁴	1.59 x 10 ⁻⁶	4.51 x 10 ⁻¹	8.88 x 10 ⁻¹
Liver	4.86 x 10 ⁻¹	2.29 x 10 ⁻⁴	7.14 x 10 ⁻⁸	6.38 x 10 ⁻⁹	6.44 x 10 ⁻¹	1.13
Pancreas	5.30 x 10 ⁻¹	6.71 x 10 ⁻⁵	8.50 x 10 ⁻⁸	5.48 x 10 ⁻⁹		5.30 x 10 ⁻¹
Spleen	5.44 x 10 ⁻¹	7.48 x 10 ⁻⁵	8.39 x 10 ⁻⁸	6.39 x 10 ⁻⁹		5.44 x 10 ⁻¹
Thymus	4.44 x 10 ⁻¹	8.37 x 10 ⁻⁵	9.04 x 10 ⁻⁸	7.43 x 10 ⁻⁹		4.44 x 10 ⁻¹
Uterus	4.32 x 10 ⁻¹	6.81 x 10 ⁻⁵	5.38 x 10 ⁻⁸	5.58 x 10 ⁻⁹		4.32 x 10 ⁻¹
Adrenals	4.39 x 10 ⁻¹	7.95 x 10 ⁻⁵	1.28 x 10 ⁻⁷	7.17 x 10 ⁻⁹		4.39 x 10 ⁻¹
Blad. Wall	5.30 x 10 ⁻¹	7.70 x 10 ⁻⁵	7.06 x 10 ⁻⁸	6.39 x 10 ⁻⁹		5.30 x 10 ⁻¹
Skin	6.23 x 10 ⁻¹	1.19 x 10 ⁻⁴	4.87 x 10 ⁻⁶	3.05 x 10 ⁻⁸	4.01 x 10 ⁻¹	1.02
Remainder	5.17 x 10 ⁻²	8.98 x 10 ⁻⁵	0.00	0.00		5.18 x 10 ⁻²
E.W.B.D.	6.38 x 10 ⁻¹	7.00 x 10 ⁻⁴	5.58 x 10 ⁻³	3.98 x 10 ⁻⁵	5.39 x 10 ⁻¹	1.18
TEEN						
Gonads	6.28 x 10 ⁻¹	2.04 x 10 ⁻⁴	5.41 x 10 ⁻⁷	1.15 x 10 ⁻⁸		6.28 x 10 ⁻¹
Breast	6.42 x 10 ⁻¹	1.81 x 10 ⁻⁴	2.75 x 10 ⁻⁶	2.16 x 10 ⁻⁸		6.42 x 10 ⁻¹
R. Marrow	1.89 x 10 ⁻¹	1.21 x 10 ⁻³	6.82 x 10 ⁻⁵	2.85 x 10 ⁻⁷	7.49 x 10 ⁻¹	9.39 x 10 ⁻¹
Lungs	6.90 x 10 ⁻¹	4.47 x 10 ⁻⁴	4.53 x 10 ⁻²	1.90 x 10 ⁻⁴	3.65 x 10 ⁻¹	1.10
Thyroid	4.31	7.54 x 10 ⁻³	1.77 x 10 ⁻⁷	9.69 x 10 ⁻⁹	1.28	5.60

Table G-29. Annual Maximum Individual Doses from Atmospheric Releases; Cumulative Impact Without the Cooling Alternatives, in Year 2000 (Millirem Per Year) (continued)

Receptor organ	Facilities					Total from all facilities
	SRP	DWPF	FMF	FPF ^a	Vogtle ^b	
TEEN ₁ (continued)						
Bone Surface	3.68 x 10 ⁻¹	3.07 x 10 ⁻³	1.06 x 10 ⁻³	4.34 x 10 ⁻⁶		3.72 x 10 ⁻¹
ST Wall	5.32 x 10 ⁻¹	7.69 x 10 ⁻⁵	8.53 x 10 ⁻⁸	6.37 x 10 ⁻⁹		5.32 x 10 ⁻¹
SI Wall	5.28 x 10 ⁻¹	1.68 x 10 ⁻⁴	5.58 x 10 ⁻⁸	5.50 x 10 ⁻⁹		5.28 x 10 ⁻¹
ULI Wall	6.55 x 10 ⁻¹	2.67 x 10 ⁻⁴	3.77 x 10 ⁻⁴	5.04 x 10 ⁻⁵		6.56 x 10 ⁻¹
LLI Wall	5.83 x 10 ⁻¹	4.33 x 10 ⁻⁴	1.15 x 10 ⁻³	1.43 x 10 ⁻⁴	3.61 x 10 ⁻¹	9.46 x 10 ⁻¹
Kidneys	4.77 x 10 ⁻¹	8.07 x 10 ⁻⁵	4.47 x 10 ⁻⁴	1.83 x 10 ⁻⁶	5.26 x 10 ⁻¹	1.00
Liver	5.28 x 10 ⁻¹	2.31 x 10 ⁻⁴	7.14 x 10 ⁻⁸	6.38 x 10 ⁻⁹	8.47 x 10 ⁻¹	1.38
Pancreas	5.71 x 10 ⁻¹	6.81 x 10 ⁻⁵	8.50 x 10 ⁻⁸	5.48 x 10 ⁻⁹		5.71 x 10 ⁻¹
Spleen	5.85 x 10 ⁻¹	7.58 x 10 ⁻⁵	8.39 x 10 ⁻⁸	6.39 x 10 ⁻⁹		5.85 x 10 ⁻¹
Thymus	4.85 x 10 ⁻¹	8.47 x 10 ⁻⁵	9.04 x 10 ⁻⁸	7.43 x 10 ⁻⁹		4.85 x 10 ⁻¹
Uterus	4.73 x 10 ⁻¹	6.91 x 10 ⁻⁵	5.38 x 10 ⁻⁸	5.58 x 10 ⁻⁹		4.73 x 10 ⁻¹
Adrenals	4.79 x 10 ⁻¹	8.05 x 10 ⁻⁵	1.28 x 10 ⁻⁷	7.17 x 10 ⁻⁹		4.79 x 10 ⁻¹
Blad. Wall	5.70 x 10 ⁻¹	7.80 x 10 ⁻⁵	7.06 x 10 ⁻⁸	6.39 x 10 ⁻⁹		5.70 x 10 ⁻¹
Skin	6.63 x 10 ⁻¹	1.20 x 10 ⁻⁴	4.87 x 10 ⁻⁶	3.05 x 10 ⁻⁸	4.15 x 10 ⁻¹	1.08
Remainder	5.50 x 10 ⁻²	1.05 x 10 ⁻⁴	0.00	0.00		5.51 x 10 ⁻²
E.W.B.D.	6.87 x 10 ⁻¹	7.64 x 10 ⁻⁴	5.60 x 10 ⁻³	3.47 x 10 ⁻⁵	5.26 x 10 ⁻¹	1.22
CHILD						
Gonads	4.85 x 10 ⁻¹	1.83 x 10 ⁻⁴	5.41 x 10 ⁻⁷	1.15 x 10 ⁻⁸		4.85 x 10 ⁻¹
Breast	5.00 x 10 ⁻¹	1.62 x 10 ⁻⁴	2.75 x 10 ⁻⁶	2.16 x 10 ⁻⁸		5.00 x 10 ⁻¹
R. Marrow	1.71 x 10 ⁻¹	9.77 x 10 ⁻⁴	5.54 x 10 ⁻⁵	2.34 x 10 ⁻⁷	1.81	1.98
Lungs	5.19 x 10 ⁻¹	2.79 x 10 ⁻⁴	2.10 x 10 ⁻²	8.77 x 10 ⁻⁵	4.24 x 10 ⁻¹	9.64 x 10 ⁻¹
Thyroid	3.47	6.13 x 10 ⁻³	1.77 x 10 ⁻⁷	9.69 x 10 ⁻⁹	2.16	5.64
Bone Surface	2.73 x 10 ⁻¹	2.27 x 10 ⁻³	8.60 x 10 ⁻⁴	3.52 x 10 ⁻⁶		2.76 x 10 ⁻¹
ST Wall	3.89 x 10 ⁻¹	7.37 x 10 ⁻⁵	8.53 x 10 ⁻⁸	6.37 x 10 ⁻⁹		3.89 x 10 ⁻¹
SI Wall	3.86 x 10 ⁻¹	1.46 x 10 ⁻⁴	5.58 x 10 ⁻⁸	5.50 x 10 ⁻⁹		3.86 x 10 ⁻¹
ULI Wall	5.07 x 10 ⁻¹	2.22 x 10 ⁻⁴	3.05 x 10 ⁻⁴	3.47 x 10 ⁻⁵		5.08 x 10 ⁻¹

Table G-29. Annual Maximum Individual Doses from Atmospheric Releases; Cumulative Impact Without the Cooling Alternatives, in Year 2000 (Millirem Per Year) (continued)

Receptor organ	Facilities					Total from all facilities
	SRP	DWPF	FMF	FPF ^a	Vogtle ^b	
CHILD (continued)						
LLI Wall	4.23 x 10 ⁻¹	3.43 x 10 ⁻⁴	9.36 x 10 ⁻⁴	9.87 x 10 ⁻⁵	4.15 x 10 ⁻¹	8.39 x 10 ⁻¹
Kidneys	3.46 x 10 ⁻¹	7.75 x 10 ⁻⁵	3.63 x 10 ⁻⁴	1.49 x 10 ⁻⁶	6.91 x 10 ⁻¹	1.04
Liver	3.78 x 10 ⁻¹	1.47 x 10 ⁻⁴	7.14 x 10 ⁻⁸	6.38 x 10 ⁻⁹	1.25	1.63
Pancreas	4.40 x 10 ⁻¹	6.49 x 10 ⁻⁵	8.50 x 10 ⁻⁸	5.48 x 10 ⁻⁹		4.40 x 10 ⁻¹
Spleen	4.54 x 10 ⁻¹	7.26 x 10 ⁻⁵	8.39 x 10 ⁻⁸	6.39 x 10 ⁻⁹		4.54 x 10 ⁻¹
Thymus	3.54 x 10 ⁻¹	8.15 x 10 ⁻⁵	9.04 x 10 ⁻⁸	7.43 x 10 ⁻⁹		3.54 x 10 ⁻¹
Uterus	3.42 x 10 ⁻¹	6.59 x 10 ⁻⁵	5.38 x 10 ⁻⁸	5.58 x 10 ⁻⁹		3.42 x 10 ⁻¹
Adrenals	3.48 x 10 ⁻¹	7.73 x 10 ⁻⁵	1.28 x 10 ⁻⁷	7.17 x 10 ⁻⁹		3.48 x 10 ⁻¹
Bladder Wall	4.39 x 10 ⁻¹	7.48 x 10 ⁻⁵	7.06 x 10 ⁻⁸	6.39 x 10 ⁻⁹		4.39 x 10 ⁻¹
Skin	5.32 x 10 ⁻¹	1.17 x 10 ⁻⁴	4.87 x 10 ⁻⁶	3.05 x 10 ⁻⁸	4.71 x 10 ⁻¹	1.00
Remainder	4.38 x 10 ⁻²	8.49 x 10 ⁻⁵	0.00	0.00		4.39 x 10 ⁻²
E.W.B.D.	5.36 x 10 ⁻¹	6.23 x 10 ⁻⁴	2.64 x 10 ⁻³	1.88 x 10 ⁻⁵	5.37 x 10 ⁻¹	1.08
INFANT						
Gonads	2.11 x 10 ⁻¹	1.19 x 10 ⁻⁴	5.41 x 10 ⁻⁷	1.15 x 10 ⁻⁸		2.11 x 10 ⁻¹
Breast	2.26 x 10 ⁻¹	1.07 x 10 ⁻⁴	2.75 x 10 ⁻⁶	2.16 x 10 ⁻⁸		2.26 x 10 ⁻¹
R. Marrow	1.32 x 10 ⁻¹	1.23 x 10 ⁻⁴	9.28 x 10 ⁻⁷	1.02 x 10 ⁻⁸	1.06	1.19
Lungs	2.30 x 10 ⁻¹	1.41 x 10 ⁻⁴	7.93 x 10 ⁻³	3.32 x 10 ⁻⁵	4.18 x 10 ⁻¹	6.56 x 10 ⁻¹
Thyroid	6.86 x 10 ⁻¹	1.05 x 10 ⁻³	1.77 x 10 ⁻⁷	9.69 x 10 ⁻⁹	4.11	4.80
Bone Surface	1.65 x 10 ⁻¹	2.68 x 10 ⁻⁴	1.35 x 10 ⁻⁵	6.53 x 10 ⁻⁸		1.65 x 10 ⁻¹
ST Wall	1.16 x 10 ⁻¹	6.79 x 10 ⁻⁵	8.53 x 10 ⁻⁸	6.37 x 10 ⁻⁹		1.16 x 10 ⁻¹
SI Wall	1.12 x 10 ⁻¹	8.27 x 10 ⁻⁵	5.58 x 10 ⁻⁸	5.50 x 10 ⁻⁹		1.12 x 10 ⁻¹
ULI Wall	2.20 x 10 ⁻¹	9.34 x 10 ⁻⁵	4.81 x 10 ⁻⁶	2.64 x 10 ⁻⁸		2.20 x 10 ⁻¹
LLI Wall	1.12 x 10 ⁻¹	8.93 x 10 ⁻⁵	1.46 x 10 ⁻⁵	6.68 x 10 ⁻⁸	3.38 x 10 ⁻¹	4.50 x 10 ⁻¹
Kidneys	1.04 x 10 ⁻¹	7.17 x 10 ⁻⁵	5.70 x 10 ⁻⁶	2.96 x 10 ⁻⁸	5.49 x 10 ⁻¹	6.53 x 10 ⁻¹
Liver	1.20 x 10 ⁻¹	9.43 x 10 ⁻⁵	7.14 x 10 ⁻⁸	6.38 x 10 ⁻⁹	1.09	1.21

Table G-29. Annual Maximum Individual Doses from Atmospheric Releases; Cumulative Impact Without the Cooling Alternatives, in Year 2000 (Millirem Per Year) (continued)

Receptor organ	Facilities					Total from all facilities
	SRP	DWPF	FMF	FPF ^a	Vogtle ^b	
INFANT (continued)						
Pancreas	1.97 x 10 ⁻¹	5.91 x 10 ⁻⁵	8.50 x 10 ⁻⁸	5.48 x 10 ⁻⁹		1.97 x 10 ⁻¹
Spleen	2.11 x 10 ⁻¹	6.68 x 10 ⁻⁵	8.39 x 10 ⁻⁸	6.39 x 10 ⁻⁹		2.11 x 10 ⁻¹
Thymus	1.11 x 10 ⁻¹	7.57 x 10 ⁻⁵	9.04 x 10 ⁻⁸	7.43 x 10 ⁻⁹		1.11 x 10 ⁻¹
Uterus	9.91 x 10 ⁻²	6.01 x 10 ⁻⁵	5.38 x 10 ⁻⁸	5.58 x 10 ⁻⁹		9.92 x 10 ⁻²
Adrenals	1.06 x 10 ⁻¹	7.15 x 10 ⁻⁵	1.28 x 10 ⁻⁷	7.17 x 10 ⁻⁹		1.06 x 10 ⁻¹
Bladder Wall	1.97 x 10 ⁻¹	6.90 x 10 ⁻⁵	7.06 x 10 ⁻⁸	6.39 x 10 ⁻⁹		1.97 x 10 ⁻¹
Skin	2.90 x 10 ⁻¹	1.11 x 10 ⁻⁴	4.87 x 10 ⁻⁶	3.05 x 10 ⁻⁸	3.97 x 10 ⁻¹	6.87 x 10 ⁻¹
Remainder	1.28 x 10 ⁻²	2.31 x 10 ⁻⁵	0.00	0.00		1.28 x 10 ⁻²
E.W.B.D.	2.22 x 10 ⁻¹	2.27 x 10 ⁻⁴	9.55 x 10 ⁻⁴	4.01 x 10 ⁻⁶	3.92 x 10 ⁻¹	6.15 x 10 ⁻¹

a. There are no radioactive liquid releases during normal FPF operations.

b. Doses from Georgia Power Company, 1985.

Table G-30. Annual Maximum Individual Doses from Liquid Releases; Cumulative Impact Without the Cooling Alternatives, in Year 2000 (Millirem Per Year)

Receptor organ	Facilities					Total from all facilities
	SRP	DWPF	FMF	FPF ^a	Vogtle ^b	
ADULT						
Gonads	1.13	4.38 x 10 ⁻³	3.88 x 10 ⁻⁷			1.13
Breast	9.65 x 10 ⁻¹	4.38 x 10 ⁻³	1.97 x 10 ⁻⁶			9.69 x 10 ⁻¹
R. Marrow	9.26 x 10 ⁻¹	4.99 x 10 ⁻⁶	2.76 x 10 ⁻⁴		6.15 x 10 ⁻¹	1.54
Lungs	1.01	4.38 x 10 ⁻³	9.54 x 10 ⁻⁸		3.02 x 10 ⁻¹	1.32
Thyroid	1.01	5.55 x 10 ⁻³	1.27 x 10 ⁻⁷		6.89 x 10 ⁻¹	1.70
Bone Surface	9.86 x 10 ⁻¹	7.37 x 10 ⁻⁶	4.29 x 10 ⁻³			9.90 x 10 ⁻¹
ST Wall	2.19 x 10 ⁻¹	4.73 x 10 ⁻³	6.12 x 10 ⁻⁶			2.24 x 10 ⁻¹
SI Wall	1.16	4.37 x 10 ⁻³	4.01 x 10 ⁻⁸			1.16
ULI Wall	4.84 x 10 ⁻¹	4.42 x 10 ⁻³	1.52 x 10 ⁻³			4.90 x 10 ⁻¹
LLI Wall	1.18	4.49 x 10 ⁻³	4.67 x 10 ⁻³		3.22 x 10 ⁻¹	1.51
Kidneys	2.20 x 10 ⁻¹	4.40 x 10 ⁻³	1.81 x 10 ⁻³		5.49 x 10 ⁻¹	7.75 x 10 ⁻¹
Liver	2.19 x 10 ⁻¹	4.39 x 10 ⁻³	5.13 x 10 ⁻⁸		1.27	1.49
Pancreas	2.19 x 10 ⁻¹	4.38 x 10 ⁻³	6.10 x 10 ⁻⁸			2.23 x 10 ⁻¹
Spleen	2.19 x 10 ⁻¹	4.38 x 10 ⁻³	6.02 x 10 ⁻⁸			2.23 x 10 ⁻¹
Thymus	2.19 x 10 ⁻¹	4.37 x 10 ⁻³	6.49 x 10 ⁻⁸			2.23 x 10 ⁻¹
Uterus	2.19 x 10 ⁻¹	4.37 x 10 ⁻³	3.86 x 10 ⁻⁸			2.23 x 10 ⁻¹
Adrenals	2.19 x 10 ⁻¹	4.37 x 10 ⁻³	9.15 x 10 ⁻⁸			2.23 x 10 ⁻¹
Blad. Wall	2.19 x 10 ⁻¹	4.37 x 10 ⁻³	5.06 x 10 ⁻⁸			2.23 x 10 ⁻¹
Skin	2.20 x 10 ⁻¹	4.37 x 10 ⁻³	3.50 x 10 ⁻⁶		3.06 x 10 ⁻³	2.27 x 10 ⁻¹
Remainder	9.87 x 10 ⁻¹	3.15 x 10 ⁻⁹				9.87 x 10 ⁻¹
E.W.B.D.	1.08	3.67 x 10 ⁻³	6.49 x 10 ⁻⁴		9.85 x 10 ⁻¹	2.07
TEEN						
Gonads	8.47 x 10 ⁻¹	3.07 x 10 ⁻³	1.30 x 10 ⁻⁶			8.50 x 10 ⁻¹
Breast	7.25 x 10 ⁻¹	3.07 x 10 ⁻³	6.60 x 10 ⁻⁶			7.28 x 10 ⁻¹
R. Marrow	7.05 x 10 ⁻¹	3.72 x 10 ⁻⁶	1.95 x 10 ⁻⁴		6.59 x 10 ⁻¹	1.36
Lungs	7.61 x 10 ⁻¹	3.07 x 10 ⁻³	3.20 x 10 ⁻⁷		2.82 x 10 ⁻¹	1.05
Thyroid	7.62 x 10 ⁻¹	3.92 x 10 ⁻³	4.24 x 10 ⁻⁷		5.89 x 10 ⁻¹	1.35
Bone Surface	7.47 x 10 ⁻¹	5.48 x 10 ⁻⁶	3.02 x 10 ⁻³			7.50 x 10 ⁻¹

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Table G-30. Annual Maximum Individual Doses from Liquid Releases; Cumulative Impact Without the Cooling Alternatives, in Year 2000 (Millirem Per Year) (continued)

Receptor organ	Facilities					Total from all facilities
	SRP	DWPF	FMF	FPF ^a	Vogtle ^b	
TEEN (continued)						
ST Wall	1.56 x 10 ⁻¹	3.32 x 10 ⁻³	2.05 x 10 ⁻⁷			1.59 x 10 ⁻¹
SI Wall	8.69 x 10 ⁻¹	3.07 x 10 ⁻³	1.34 x 10 ⁻⁷			8.72 x 10 ⁻¹
ULI Wall	3.57 x 10 ⁻¹	3.10 x 10 ⁻³	1.07 x 10 ⁻³			3.61 x 10 ⁻¹
LLI Wall	8.88 x 10 ⁻¹	3.15 x 10 ⁻³	3.29 x 10 ⁻³		2.41 x 10 ⁻¹	1.14
Kidneys	1.56 x 10 ⁻¹	3.09 x 10 ⁻³	1.28 x 10 ⁻³		5.14 x 10 ⁻¹	6.74 x 10 ⁻¹
Liver	1.56 x 10 ⁻¹	3.08 x 10 ⁻³	1.72 x 10 ⁻⁷		1.25	1.41
Pancreas	1.55 x 10 ⁻¹	3.07 x 10 ⁻³	2.04 x 10 ⁻⁷			1.58 x 10 ⁻¹
Spleen	1.56 x 10 ⁻¹	3.07 x 10 ⁻³	2.02 x 10 ⁻⁷			1.59 x 10 ⁻¹
Thymus	1.56 x 10 ⁻¹	3.07 x 10 ⁻³	2.17 x 10 ⁻⁷			1.59 x 10 ⁻¹
Uterus	1.55 x 10 ⁻¹	3.07 x 10 ⁻³	1.29 x 10 ⁻⁷			1.58 x 10 ⁻¹
Adrenals	1.56 x 10 ⁻¹	3.07 x 10 ⁻³	3.07 x 10 ⁻⁷			1.59 x 10 ⁻¹
Bladder Wall	1.56 x 10 ⁻¹	3.07 x 10 ⁻³	1.70 x 10 ⁻⁷			1.59 x 10 ⁻¹
Skin	1.58 x 10 ⁻¹	3.07 x 10 ⁻³	1.17 x 10 ⁻⁵		1.71 x 10 ⁻²	1.78 x 10 ⁻¹
Remainder	7.51 x 10 ⁻¹	2.40 x 10 ⁻⁹				7.51 x 10 ⁻¹
E.W.B.D.	8.15 x 10 ⁻¹	2.58 x 10 ⁻³	4.58 x 10 ⁻⁴		6.01 x 10 ⁻¹	1.42
CHILD						
Gonads	4.51 x 10 ⁻¹	2.99 x 10 ⁻³	2.72 x 10 ⁻⁷			4.54 x 10 ⁻¹
Breast	3.98 x 10 ⁻¹	2.99 x 10 ⁻³	1.38 x 10 ⁻⁶			4.01 x 10 ⁻¹
R. Marrow	3.23 x 10 ⁻¹	2.21 x 10 ⁻⁶	1.84 x 10 ⁻⁴		8.19 x 10 ⁻¹	1.14
Lungs	4.14 x 10 ⁻¹	2.99 x 10 ⁻³	6.68 x 10 ⁻⁸		3.56 x 10 ⁻¹	7.73 x 10 ⁻¹
Thyroid	4.14 x 10 ⁻¹	3.64 x 10 ⁻³	8.87 x 10 ⁻⁸		1.14	1.56
Bone Surface	3.61 x 10 ⁻¹	3.67 x 10 ⁻⁶	2.86 x 10 ⁻³			3.64 x 10 ⁻¹
ST Wall	1.50 x 10 ⁻¹	3.18 x 10 ⁻³	4.29 x 10 ⁻⁸			1.53 x 10 ⁻¹
SI Wall	4.61 x 10 ⁻¹	2.99 x 10 ⁻³	2.80 x 10 ⁻⁸			4.64 x 10 ⁻¹
ULI Wall	2.40 x 10 ⁻¹	3.01 x 10 ⁻³	1.02 x 10 ⁻³			2.44 x 10 ⁻¹
LLI Wall	4.76 x 10 ⁻¹	3.05 x 10 ⁻³	3.12 x 10 ⁻³		2.84 x 10 ⁻¹	7.66 x 10 ⁻¹

Table G-30. Annual Maximum Individual Doses from Liquid Releases; Cumulative Impact Without the Cooling Alternatives, in Year 2000 (Millirem Per Year) (continued)

Receptor organ	Facilities					Total from all facilities
	SRP	DWPF	FMF	FPF ^a	Vogtle ^b	
CHILD (continued)						
Kidneys	1.50 x 10 ⁻¹	3.00 x 10 ⁻³	1.21 x 10 ⁻³		5.67 x 10 ⁻¹	7.21 x 10 ⁻¹
Liver	1.50 x 10 ⁻¹	3.00 x 10 ⁻³	3.59 x 10 ⁻⁸		1.23	1.38
Pancreas	1.50 x 10 ⁻¹	2.99 x 10 ⁻³	4.27 x 10 ⁻⁸			1.53 x 10 ⁻¹
Spleen	1.50 x 10 ⁻¹	2.99 x 10 ⁻³	4.21 x 10 ⁻⁸			1.53 x 10 ⁻¹
Thymus	1.50 x 10 ⁻¹	2.99 x 10 ⁻³	4.54 x 10 ⁻⁸			1.53 x 10 ⁻¹
Uterus	1.50 x 10 ⁻¹	2.99 x 10 ⁻³	2.71 x 10 ⁻⁸			1.53 x 10 ⁻¹
Adrenals	1.50 x 10 ⁻¹	2.99 x 10 ⁻³	6.41 x 10 ⁻⁸			1.53 x 10 ⁻¹
Bladder Wall	1.50 x 10 ⁻¹	2.99 x 10 ⁻³	3.55 x 10 ⁻⁸			1.53 x 10 ⁻¹
Skin	1.50 x 10 ⁻¹	2.99 x 10 ⁻³	2.45 x 10 ⁻⁶		3.58 x 10 ⁻³	1.57 x 10 ⁻¹
Remainder	3.28 x 10 ⁻¹	1.05 x 10 ⁻⁹				3.28 x 10 ⁻¹
E.W.B.D.	4.25 x 10 ⁻¹	2.50 x 10 ⁻³	4.33 x 10 ⁻⁴		4.32 x 10 ⁻¹	8.60 x 10 ⁻¹
INFANT						
Gonads	9.76 x 10 ⁻²	1.90 x 10 ⁻³				9.95 x 10 ⁻²
Breast	9.71 x 10 ⁻²	1.90 x 10 ⁻³				4.90 x 10 ⁻²
R. Marrow	2.13 x 10 ⁻²	6.89 x 10 ⁻⁷	1.14 x 10 ⁻⁴		3.39 x 10 ⁻²	5.53 x 10 ⁻²
Lungs	9.72 x 10 ⁻²	1.90 x 10 ⁻³			2.39 x 10 ⁻¹	3.38 x 10 ⁻²
Thyroid	9.72 x 10 ⁻²	2.21 x 10 ⁻³			1.42	1.52
Bone Surface	4.45 x 10 ⁻²	1.51 x 10 ⁻⁶	1.77 x 10 ⁻³			4.63 x 10 ⁻²
ST Wall	9.47 x 10 ⁻²	1.99 x 10 ⁻³				9.67 x 10 ⁻²
SI Wall	9.77 x 10 ⁻²	1.90 x 10 ⁻³				9.96 x 10 ⁻²
ULI Wall	9.84 x 10 ⁻²	1.91 x 10 ⁻³	6.31 x 10 ⁻⁴			1.01 x 10 ⁻¹
LLI Wall	1.06 x 10 ⁻¹	1.93 x 10 ⁻³	1.93 x 10 ⁻³		2.39 x 10 ⁻¹	3.49 x 10 ⁻¹
Kidneys	9.49 x 10 ⁻²	1.90 x 10 ⁻³	7.49 x 10 ⁻⁴		2.51 x 10 ⁻¹	3.49 x 10 ⁻¹
Liver	9.48 x 10 ⁻²	1.90 x 10 ⁻³			2.82 x 10 ⁻¹	3.79 x 10 ⁻¹
Pancreas	9.47 x 10 ⁻²	1.90 x 10 ⁻³				9.66 x 10 ⁻²
Spleen	9.47 x 10 ⁻²	1.90 x 10 ⁻³				9.66 x 10 ⁻²

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Table G-30. Annual Maximum Individual Doses from Liquid Releases; Cumulative Impact Without the Cooling Alternatives, in Year 2000 (Millirem Per Year) (continued)

Receptor organ	Facilities ^a					Total from all facilities
	SRP	DWPF	FMF	FPF ^a	Vogtle ^b	
INFANT (continued)						
Thymus	9.47 x 10 ⁻²	1.90 x 10 ⁻³				9.66 x 10 ⁻²
Uterus	9.47 x 10 ⁻²	1.90 x 10 ⁻³				9.66 x 10 ⁻²
Adrenals	9.47 x 10 ⁻²	1.90 x 10 ⁻³				9.66 x 10 ⁻²
Bladder Wall	9.47 x 10 ⁻²	1.90 x 10 ⁻³				9.66 x 10 ⁻²
Skin	9.47 x 10 ⁻²	1.90 x 10 ⁻³				9.66 x 10 ⁻²
Remainder	3.19 x 10 ⁻³	1.01 x 10 ⁻¹¹				3.19 x 10 ⁻³
E.W.B.D.	8.51 x 10 ⁻²	1.58 x 10 ⁻³	2.68 x 10 ⁻⁴		2.42 x 10 ⁻¹	3.29 x 10 ⁻¹

a. There are no radioactive liquid releases during normal FPF operations.

b. Doses from Georgia Power Company, 1985.

Table G-31. Annual Maximum Individual Doses from Combined Atmospheric and Liquid Releases; Cumulative Impact Without the Cooling Alternatives, in Year 2000 (Millirem Per Year)

Receptor organ	Total from all facilities			
	Adult	Teen	Child	Infant
Gonads	1.72	1.48	9.39×10^{-1}	3.11×10^{-1}
Breast	1.57	1.37	9.01×10^{-1}	3.25×10^{-1}
R. Marrow	2.29	2.30	3.21	1.25
Lungs	2.35	2.15	1.74	9.94×10^{-1}
Thyroid	6.48	6.95	7.19	6.32
Bone Surface	1.35	1.12	6.40×10^{-1}	2.12×10^{-1}
ST Wall	7.12×10^{-1}	6.91×10^{-1}	5.42×10^{-1}	2.13×10^{-1}
SI Wall	1.65	1.40	8.50×10^{-1}	2.12×10^{-1}
ULI Wall	1.11	1.02	7.52×10^{-1}	3.21×10^{-1}
LLI Wall	2.42	2.08	1.61	7.99×10^{-1}
Kidneys	1.66	1.68	1.76	1.00
Liver	2.62	2.78	3.01	1.59
Pancreas	7.53×10^{-1}	7.29×10^{-1}	5.93×10^{-1}	2.94×10^{-1}
Spleen	7.67×10^{-1}	7.44×10^{-1}	6.07×10^{-1}	3.08×10^{-1}
Thymus	6.67×10^{-1}	6.44×10^{-1}	5.07×10^{-1}	2.08×10^{-1}
Uterus	6.55×10^{-1}	6.31×10^{-1}	4.95×10^{-1}	1.96×10^{-1}
Adrenals	6.62×10^{-1}	6.38×10^{-1}	5.01×10^{-1}	2.03×10^{-1}
Bladder Wall	7.53×10^{-1}	7.29×10^{-1}	5.92×10^{-1}	2.94×10^{-1}
Skin	1.25	1.26	1.16	7.84×10^{-1}
Remainder	1.04	8.06×10^{-1}	3.72×10^{-1}	1.60×10^{-2}
E.W.B.D.	3.25	2.64	1.94	9.44×10^{-1}

Table G-32. Annual Collective Doses from Atmospheric and Liquid Releases; Cumulative Impact Without the Cooling Alternatives, in Year 2000 (Person-Rem Per Year)

Receptor organ	Facilities					Total from all facilities
	SRP	DWPF	FMF	PPF ^a	Vogtle ^b	
ATMOSPHERIC						
Gonads	4.12 x 10 ¹	3.52 x 10 ⁻²	3.77 x 10 ⁻⁴	7.98 x 10 ⁻⁶		4.12 x 10 ¹
Breast	4.12 x 10 ¹	3.22 x 10 ⁻²	1.91 x 10 ⁻³	1.50 x 10 ⁻⁵		4.12 x 10 ¹
R. Marrow	1.04 x 10 ¹	8.03 x 10 ⁻²	3.02 x 10 ⁻³	1.68 x 10 ⁻⁵	3.24 x 10 ⁻³	1.08 x 10 ¹
Lungs	4.87 x 10 ¹	6.41 x 10 ⁻²	6.14	2.57 x 10 ⁻²	4.82 x 10 ⁻¹	5.54 x 10 ¹
Thyroid	3.58 x 10 ²	6.64 x 10 ⁻¹	1.23 x 10 ⁻⁴	6.75 x 10 ⁻⁶	6.12 x 10 ⁻¹	3.59 x 10 ²
Bone Surface	3.02 x 10 ¹	2.26 x 10 ⁻¹	4.63 x 10 ⁻²	1.96 x 10 ⁻⁴		3.05 x 10 ¹
ST Wall	3.67 x 10 ¹	2.16 x 10 ⁻²	5.94 x 10 ⁻⁵	4.43 x 10 ⁻⁶		3.67 x 10 ¹
SI Wall	3.62 x 10 ¹	2.34 x 10 ⁻²	3.89 x 10 ⁻⁵	3.83 x 10 ⁻⁶		3.62 x 10 ¹
ULI Wall	4.25 x 10 ¹	3.28 x 10 ⁻²	1.65 x 10 ⁻²	4.15 x 10 ⁻³		4.26 x 10 ¹
LLI Wall	4.07 x 10 ¹	4.25 x 10 ⁻²	5.03 x 10 ⁻²	1.18 x 10 ⁻²	4.76 x 10 ⁻¹	4.13 x 10 ¹
Kidneys	3.41 x 10 ¹	2.30 x 10 ⁻²	1.95 x 10 ⁻²	8.42 x 10 ⁻⁵	4.79 x 10 ⁻¹	3.46 x 10 ¹
Liver	3.91 x 10 ¹	4.21 x 10 ⁻²	4.97 x 10 ⁻⁵	4.44 x 10 ⁻⁶	4.83 x 10 ⁻¹	3.96 x 10 ¹
Pancreas	3.77 x 10 ¹	1.88 x 10 ⁻²	5.92 x 10 ⁻⁵	3.81 x 10 ⁻⁶		3.77 x 10 ¹
Spleen	3.86 x 10 ¹	2.13 x 10 ⁻²	5.84 x 10 ⁻⁵	4.45 x 10 ⁻⁶		3.86 x 10 ¹
Thymus	3.42 x 10 ¹	2.42 x 10 ⁻²	6.29 x 10 ⁻⁵	5.17 x 10 ⁻⁶		3.42 x 10 ¹
Uterus	3.34 x 10 ¹	1.91 x 10 ⁻²	3.75 x 10 ⁻⁵	3.89 x 10 ⁻⁶		3.34 x 10 ¹
Adrenals	3.41 x 10 ¹	2.28 x 10 ⁻²	8.88 x 10 ⁻⁵	4.99 x 10 ⁻⁶		3.41 x 10 ¹
Bladder Wall	3.77 x 10 ¹	2.20 x 10 ⁻²	4.91 x 10 ⁻⁵	4.45 x 10 ⁻⁶		3.77 x 10 ¹
Skin	4.27 x 10 ¹	3.63 x 10 ⁻²	3.39 x 10 ⁻³	2.13 x 10 ⁻⁵	7.58 x 10 ⁻¹	4.35 x 10 ¹
Remainder	2.77	4.22 x 10 ⁻³				2.77
E.W.B.D.	4.78 x 10 ¹	9.37 x 10 ⁻²	7.44 x 10 ⁻¹	4.07 x 10 ⁻³	4.80 x 10 ⁻¹	4.91 x 10 ¹
LIQUID						
Gonads	3.52 x 10 ¹	6.50 x 10 ⁻¹	3.88 x 10 ⁻⁶			3.59 x 10 ¹
Breast	3.47 x 10 ¹	6.50 x 10 ⁻¹	1.97 x 10 ⁻⁵			3.53 x 10 ¹
R. Marrow	9.02	2.47 x 10 ⁻⁴	3.93 x 10 ⁻²			9.06
Lungs	3.48 x 10 ¹	6.50 x 10 ⁻¹	9.54 x 10 ⁻⁷			3.55 x 10 ¹
Thyroid	3.48 x 10 ¹	7.60 x 10 ⁻¹	1.27 x 10 ⁻⁶			3.56 x 10 ¹
Bone Surface	1.71 x 10 ¹	5.28 x 10 ⁻⁴	6.10 x 10 ⁻¹			1.77 x 10 ¹

Table G-32. Annual Collective Doses from Atmospheric and Liquid Releases; Cumulative Impact Without the Cooling Alternatives, in Year 2000 (Person-Rem Per Year) (continued)

Receptor organ	Facilities					Total from all facilities
	SRP	DWPF	FMF	FPF ^a	Vogtle ^b	
LIQUID (continued)						
ST Wall	3.24 x 10 ¹	6.83 x 10 ⁻¹	6.12 x 10 ⁻⁷			3.31 x 10 ¹
SI Wall	3.53 x 10 ¹	6.50 x 10 ⁻¹	4.01 x 10 ⁻⁷			3.60 x 10 ¹
ULI Wall	3.42 x 10 ¹	6.56 x 10 ⁻¹	2.16 x 10 ⁻¹			3.51 x 10 ¹
LLI Wall	3.81 x 10 ¹	6.62 x 10 ⁻¹	6.63 x 10 ⁻¹			3.95 x 10 ¹
Kidneys	3.26 x 10 ¹	6.52 x 10 ⁻¹	2.57 x 10 ⁻¹			3.35 x 10 ¹
Liver	3.24 x 10 ¹	6.52 x 10 ⁻¹	5.13 x 10 ⁻⁷			3.31 x 10 ¹
Pancreas	3.24 x 10 ¹	6.52 x 10 ⁻¹	6.10 x 10 ⁻⁷			3.31 x 10 ¹
Spleen	3.24 x 10 ¹	6.52 x 10 ⁻¹	6.02 x 10 ⁻⁷			3.31 x 10 ¹
Thymus	3.24 x 10 ¹	6.50 x 10 ⁻¹	6.49 x 10 ⁻⁷			3.31 x 10 ¹
Uterus	3.24 x 10 ¹	6.50 x 10 ⁻¹	3.86 x 10 ⁻⁷			3.31 x 10 ¹
Adrenals	3.24 x 10 ¹	6.50 x 10 ⁻¹	9.15 x 10 ⁻⁷			3.31 x 10 ¹
Bladder Wall	3.24 x 10 ¹	6.50 x 10 ⁻¹	5.06 x 10 ⁻⁷			3.31 x 10 ¹
Skin	3.24 x 10 ¹	6.50 x 10 ⁻¹	3.05 x 10 ⁻⁵			3.31 x 10 ¹
Remainder	2.94	9.41 x 10 ⁻⁹				2.94
E.W.B.D.	3.09 x 10 ¹	5.42 x 10 ⁻¹	9.21 x 10 ⁻²			3.15 x 10 ¹
COMBINED ATMOSPHERIC AND LIQUID						
Gonads						7.71 x 10 ¹
Breast						7.66 x 10 ¹
R. Marrow						1.99 x 10 ¹
Lungs						9.09 x 10 ¹
Thyroid						3.95 x 10 ²
Bone Surface						4.81 x 10 ¹
ST Wall						6.98 x 10 ¹
SI Wall						7.22 x 10 ¹
ULI Wall						7.77 x 10 ¹
LLI Wall						8.07 x 10 ¹

Table G-32. Annual Collective Doses from Atmospheric and Liquid Releases; Cumulative Impact Without the Cooling Alternatives, in Year 2000 (Person-Rem Per Year) (continued)

Receptor organ	Facilities					Total from all facilities
	SRP	DWPF	FMF	FPF ^a	Vogtle ^b	
COMBINED ATMOSPHERIC AND LIQUID (continued)						
Kidneys						6.82 x 10 ¹
Liver						7.27 x 10 ¹
Pancreas						7.08 x 10 ¹
Spleen						7.17 x 10 ¹
Thymus						6.73 x 10 ¹
Uterus						6.65 x 10 ¹
Adrenals						6.72 x 10 ¹
Bladder Wall						7.08 x 10 ¹
Skin						7.66 x 10 ¹
Remainder						5.72
E.W.B.D.						8.07 x 10 ¹

a. There are no radioactive liquid releases during normal FPF operations.

b. Doses from Georgia Power Company, 1985; liquid dose is "negligible."

Table G-33. Effective Whole-Body Doses to the Maximally Exposed Individual from Cumulative Atmospheric Releases, Comparison of Cooling Alternatives (Millirem per Year)

Cooling alternative	Adult	Teen	Child	Infant
Present cooling system	1.18	1.22	1.08	6.15×10^{-1}
Once-through cooling towers (K- and C-Reactors)	1.18	1.22	1.08	6.15×10^{-1}
Recirculating cooling towers (K- and C-Reactors)	1.18	1.22	1.08	6.15×10^{-1}

Table G-34. Effective Whole-Body Doses to the Maximally Exposed Individual from Cumulative Liquid Releases to Savannah River, Comparison of Cooling Alternatives (Millirem per Year)

Cooling alternative	Adult	Teen	Child	Infant
Present cooling system	2.07	1.42	8.60×10^{-1}	3.29×10^{-1}
Once-through cooling towers (K- and C-Reactors)	2.07	1.42	8.60×10^{-1}	3.29×10^{-1}
Recirculating cooling towers (K- and C-Reactors)	1.88	1.27	7.95×10^{-1}	3.27×10^{-1}

BC-22

Table G-35. Effective Whole-Body Doses to the Maximally Exposed Individual from Cumulative Atmospheric and Liquid Releases, Comparison of Cooling Alternatives (Millirem per Year)

Cooling alternative	Adult	Teen	Child	Infant
Present cooling system	3.25	2.64	1.94	9.44×10^{-1}
Once-through cooling towers (K- and C-Reactors)	3.25	2.64	1.94	9.44×10^{-1}
Recirculating cooling towers (K- and C-Reactors)	3.06	2.49	1.88	9.42×10^{-1}

BC-22

The BEIR III report identifies three categories of radiation-induced human health effects: (1) cancer, (2) genetic disorders, and (3) somatic effects other than cancer. The committee believes cancer induction is the most important effect of low-dose radiation. In this context, "low dose" refers to

Table G-36. Comparison of 80-Kilometer Collective Dose from Increased Release of Tritium to the Atmosphere with Present Cooling Systems: Once-Through Cooling Towers for K- and C-Reactors and Recirculating Cooling Towers for K- and C-Reactors (Person-Rem per Year)

Cooling alternative	Effective whole body
Present cooling systems (no action)	4.91×10^1
Once-through cooling towers	4.91×10^1
Recirculating cooling towers	4.92×10^1

Table G-37. Comparison of Collective Dose from Reduced Liquid Releases to Savannah River with Present Cooling Systems: Once-Through Cooling Towers for K- and C-Reactors and Recirculating Cooling Towers for K- and C-Reactors (Person-Rem per Year)

Cooling alternative	Effective whole body
Present cooling systems (no action)	3.15×10^1
Once-through cooling towers	3.14×10^1
BC-22 Recirculating cooling towers	3.03×10^1

Table G-38. Comparison of Collective Dose from Increased Atmospheric Releases and Reduced Liquid Releases with Present Cooling Systems: Once-Through Cooling Towers for K- and C-Reactors and Recirculating Cooling Towers for K- and C-Reactors (Person-Rem per Year)

Cooling alternative	Effective whole body
Present cooling systems (no action)	8.07×10^1
Once-through cooling towers	8.05×10^1
BC-22 Recirculating cooling towers	7.96×10^1

doses as high as a few rads per person per year. Natural background radiation ranges from 0.1 to 0.2 rad per person per year. Genetic effects of low-level radiation have been well documented and are addressed in detail in the BEIR III report. Somatic effects other than cancer include cataract induction and fertility impairment. The BEIR III report concludes that low-dose exposure of

human populations does not increase the risk of somatic effects other than cancer and developmental changes in unborn children. The report also indicates that developmental changes in unborn children are probably not caused by radiation at or below natural background levels. For these reasons, only cancer and genetic disorders are considered in this analysis.

Cancer data from the Japanese survivors of atomic bomb blasts are used in most of the analyses in the BEIR III report. A major question addressed by the BEIR III report is how to extrapolate the cancer risks observed at the relatively high dose rates down to the lower dose rates caused by most nuclear facilities. The BEIR III report adopted a parametric family of functions to complete this extrapolation. The linear model represents an upper limit or maximum risk; the linear-quadratic model, an intermediate or probable risk; and the quadratic model, a low-limit or minimum risk. These functions have been suggested by the report for low linear energy transfer (LET) radiation. This type radiation includes gamma and X-radiation and electrons (beta particles). High-LET radiation includes alpha particles encountered in the decay of radionuclides in the natural uranium decay chain. The BEIR III report states that for High-LET radiation, "the linear hypothesis is less likely to lead to over estimates of risk and may, in fact, lead to underestimates." The linear model would, therefore, represent the best estimate for probable risk from this type radiation.

One radiation-induced cancer characteristic is that it takes a long time to develop, known as the latent period. Leukemia has a characteristically short latent period (less than 25 years), while other cancers can have latent periods for as long as the life span of an individual. Because only about 35 years of cancer data have been collected on the survivors of atomic bomb blasts, the data do not account for all the cancers that might develop because of the bombs' radiation. Two projection models have been developed to account for these future cancer deaths: (1) the absolute risk projection model, which assumes that the cancer rate (risk per year) observed since the atomic bomb blasts will continue throughout the life spans of those exposed; and (2) the relative-risk model, which assumes the excess radiation-induced risk is proportional to the natural incidence of cancer with age. The relative-risk model results in cancer-risk estimates greater than those predicted by the absolute model. However, the BEIR III report states that the absolute model is generally more applicable to most forms of cancer. The cancer-risk estimates used represent an average of those calculated using the absolute- and relative-risk models.

Only low-LET radiation is associated with the changes of radioactivity released to the environment resulting from the implementation of the alternative cooling water systems. For existing operations, the contribution of high-LET radiation has been found to be much less than that from low-LET radiation.

Health-effects estimators for low-LET radiation were derived for use in estimating health effects based on an evaluation of the data presented in the BEIR III report. The resulting health-effects estimators used in this document are summarized in Table G-39. They total 120 fatalities per million person-rem. The health-effects estimate for genetic effects used in this document is 257 genetic effects per million person-rem of radiation, received by the gonads.

These health-effects estimators are the best estimate of risk based on present data. The estimators could vary widely, depending on the models used. The low-LET estimators could range from near 0 to as high as 400 per million person-rem. For genetic effects, the risk estimator could range from 60 to 1100 per million person-rem.

Table G-39. Health Effects Estimators Used in the Evaluation of Radiation Health Effects

Organ/cancer	Cancer fatalities per million person-rem
	Low-LET radiation ^{a, b}
Leukemia and bone cancer ^c	20
Lung	28
Liver	6.5
Kidney and bladder ^c	3.2
Intestinal tract ^c	5.3
Thyroid	6.9
Breast	9.8
Pancreas	7.9
Stomach	11
Other	19
Total	120

a. LET = linear energy transfer.

b. The arithmetic average of the absolute and relative model values has been used. In addition, the linear-quadratic model has been assumed.

c. For multiple organs, the health effects estimators are multiplied by the organ that produces the highest collective organ dose.

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APPENDIX H

SCOPING COMMENTS AND RESPONSES

Pursuant to the National Environmental Policy Act of 1969, the U.S. Department of Energy (DOE) announced its intent to prepare an environmental impact statement (EIS) on cooling water systems for C- and K-Reactors and the D-Area coal-fired powerhouse at the Savannah River Plant (SRP) in the Federal Register on July 29, 1985 (50 FR 145). The Notice of Intent solicited comments and suggestions from interested agencies, organizations, and the general public for consideration in preparing the EIS. Comments were received by mail and at a scoping meeting held in Aiken, South Carolina, on August 19, 1985. Written comments were received until August 31, 1985.

During the public comment period, 12 individuals, agencies, and organizations presented written or oral comments--two individuals provided written comments at one of the public scoping meetings and more detailed written comments following the scoping meetings. Individuals, agencies, and organizations providing comments are listed on Table H-1.

The comments received at the public scoping meeting or in writing during the public comment period are presented in Table H-2. Table H-2 also provides responses to the comments raised by individuals, agencies, and organizations on the scope of the EIS.

Table H-3 provides a summary listing of the topics contained in the comments, with references to the appropriate chapters and sections of the proposed EIS outline.

Copies of the oral statements and scoping letters have been made available for public inspection at the DOE Public Reading Room located at the University Library, 2nd Floor, University of South Carolina, Aiken Campus, University Parkway, Aiken, South Carolina, and the Freedom of Information Reading Room, Room 1E-190, Forrestal Building, 1000 Independence Avenue, SW, Washington, DC.

Table H-1. Index of Agencies, Organizations, and Individuals
Submitting Scoping Comments

Designation	Agency, organization, or individual	Page
A	Sheppard N. Moore, Chief of NEPA Review Staff for Region IV, U.S. Environmental Protection Agency	H-3
B	Bart Ruiter, representing the South Carolina Department of Health and Environmental Control	H-5
C	Mr. W. P. Bebbington	H-6
D	Frances Hart, representing the Energy Research Foundation	H-10
E	Mr. Karl Herde	H-12
F	Ms. Dorcas Elledge	H-15
G	Jean Robinson, on behalf of W. F. Lawless	H-16
H	Mr. Sam Schillaci	H-19
I	Mr. William McDaniel	H-20
J	Zoe G. Tsagos, representing the League of Women Voters in Northern Beaufort County	H-24
K	Roger L. Banks, representing the South Carolina Office of the U.S. Department of the Interior, Fish and Wildlife Service	H-26
L	J. W. Morris	H-28

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	STATEMENT OF MR. SHEPPARD MOORE Chief, NEPA Review Staff Environmental Protection Agency Region IV Atlanta, Georgia My name is Sheppard N. Moore. I'm chief of the NEPA Review Staff at Region IV, U.S. Environmental Protection Agency, Atlanta, Georgia. We at EPA are pleased to see that the Department of Energy is preparing an environmental impact statement as part of the decisionmaking process concerning cooling water systems at the Savannah River Plant. EPA has a long history of involvement with environmental matters at SRP, and we look forward to working with DOE and the State of South Carolina during the preparation of this EIS.	
A-1	Relevant to the proposed EIS, EPA believes that the environmental and nonenvironmental issues identified by DOE in their news announcement dated July 29th, 1985, for this EIS are important. Of the issues listed by DOE, EPA is particularly concerned with potential wetland impacts, water quality issues, and radionuclide effects as well as fishery implications, air quality, drinking water quality, and the cumulative effects. Recommended additions to the DOE list are possible floodplain, groundwater, and noise impacts.	A discussion of impacts associated with floodplain/wetlands, groundwater, and noise will be presented in Chapter 4 of the EIS. Appendix F will present a wetlands/floodplains assessment pursuant to Executive Orders 11988 and 11990, and DOE's regulations for compliance with floodplain/wetlands environmental review requirements (10 CFR 1022).
A-2	Since one of our major concerns at EPA is the protection of wetlands, we wish to emphasize that any wetland acreage that may be lost should be quantified and characterized for each action alternative. Avoidance of impacts and mitigation for unavoidable impacts should be addressed for wetlands as well as other areas.	Wetland acreage that will be gained or lost will be quantified and characterized for each cooling water alternative in Chapter 4 and Appendix F of the EIS.
A-3	We appreciate the numerous alternatives considered by DOE for the cooling effluent of C- and K-Reactors and the D-Area coal-fired power plant. In our view, at least two and preferably three feasible action alternatives should be addressed in the EIS in similar detail for each facility so that the EIS will be a decisionmaking document and a final preferred alternative can be selected. Similarly, the no-action alternative should be thoroughly addressed. I appreciate the opportunity to be here. I guess my main purpose is to hear what you and the others have to say. Thank you.	Chapter 4 of the EIS will discuss the environmental impacts of the reasonable cooling water alternatives for the C-Reactor, K-Reactor, and the D-Area coal-fired powerhouse. In addition, the no-action alternative will be addressed.

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
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ADDITIONAL STATEMENTS OF MR. MOORE
EVENING PUBLIC SCOPING MEETING

Since I spoke this morning and gave you a copy of my written statement, I won't repeat that. I do want to say for the people that are here this evening that were not here this morning that I appreciate the opportunity to be here. I want to thank you for inviting EPA and the State to participate in this meeting.

I would like to add one thing to what Pat had to say about the slide on NEPA. It's true that NEPA requires that the Federal decisionmakers factor the environment into their decision-making process, but I think the really important benefit from NEPA is the public involvement.

I'm a little disappointed at the number of people here tonight, and I would like to encourage anyone that is here that has something to say that from experience I can say that government does listen to what people say. That's what NEPA has done for us is provided the mechanism for public involvement and how we, the government, carry out their business.

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
STATEMENT OF MR. BART RUITER SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL		
	My name is Bart Ruiter. I am with the Department of Health and Environmental Control. On January 3, 1984, the South Carolina Department of Health and Environmental Control entered into a Consent Order with the United States Department of Energy Savannah River Plant. This Consent Order allowed the Savannah River Plant temperature requirements in the National Pollutant Discharge Elimination System (NPDES) permit to be temporarily superseded by those requirements contained in the Order. Outfalls affected by this Order are specifically C-Reactor, P-Reactor, K-Reactor, and D-Area powerhouse. In this Consent Order, SRP agreed to, one, complete comprehensive studies on the thermal effects of all operations at the Savannah River Plant upon the waters of the State of South Carolina; two, complete and submit the thermal mitigation studies to DHEC within nine months of the signing of the Consent Order; three, implement the alternative approved by DHEC under a schedule to be established by DHEC in a subsequent order; and four, submit and actively support appropriate funding requests to accomplish any actions resulting from the thermal studies. To date, we are currently near completion in establishing an implementation schedule under an amendment to the Consent Order with SRP which takes into account the National Environmental Policy Act process.	
B-1	As SRP proceeds through this NEPA process and eventually selects a final alternative for the mitigation of thermal restrictions on the above outfalls, the selected alternatives for C-Reactor, K-Reactor, P-Reactor, and D-Area powerhouse must meet the specified limitations of the NPDES permit and/or temperature limits that are consistent with the requirements or intent of the Clean Water Act and the South Carolina Water Classifications and Standards. Thank you for allowing the Department to express its comments.	The ability of each of the cooling water alternatives considered in the EIS to meet applicable regulatory requirements will be discussed in Chapters 2 and 4.

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
STATEMENT OF MR. W. P. BEBBINGTON		
	I have submitted a letter containing more specific comments than I intend to make here. I wish, now, to direct the attention of the audience and the other participants to some important general facts regarding the Savannah River Plant and its history. The 200,000-acre site was purchased with taxpayers' money in 1950 to ensure that the public would be adequately protected from possible harm from the nuclear operations within the site and that there would be adequate protection of the operations against incursions. It was recognized at the outset that, while the operators could and would be expected to hold releases of radioactive and other undesirable wastes to levels that were as low as practical, very large amounts of heat would necessarily be discharged from the reactors. The heat would be released as heated water, and the Savannah River had to be protected against biological damage from it. By placing the reactors near the center of the site and allowing the water to flow to the river through the beds of existing small streams, the temperature of the water, when it entered the river, would be low enough to preclude damage. To verify that there was no thermal damage to the river, Dr. Ruth Patrick and her team of limnologists from the Academy of Natural Sciences of Philadelphia were commissioned to determine exactly and comprehensively the condition of the river before plant startup and to monitor it carefully for changes while the plant operated. Dr. Patrick has stated repeatedly and unequivocally that thermal effluents from SRP have had no adverse effects on the river. The streams that carry reactor cooling water to the river are small, rise on the site, and have no significant economic, recreational, or unique ecological values. The hot water has destroyed vegetation and discouraged animal life; but, as was demonstrated in Steel Creek after L-Reactor was shut down, the damage is not permanent. Most of the land of the site is outside the restricted production areas. This land has not been neglected and allowed to deteriorate. Hundreds of millions of trees were planted and	Comments noted.

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	managed as a productive forest. The University of Georgia established there a field laboratory of ecology under the overall direction of Dr. Eugene P. Odum, one of the nation's most revered ecologists. Later, the site was designated as the first National Environmental Research Park. It has attracted students and faculty from many universities for summer and longer residences. A former director of the Savannah River Ecology Laboratory said, "If it hadn't been for AEC support, there wouldn't be a science of ecology." The well-protected site has become an important wildlife refuge. After three decades of plant operation without public harm and with great ecological benefit, the State of South Carolina has intruded with costly, unnecessary, and indeed environmentally detrimental demands that can be met only at great public expense at a time when there is a terribly urgent need to reduce the federal deficit. The cost of the L-Reactor lake project will not be 25 or 40 million dollars but, when delay times and productivity losses are taken into account, in the hundreds of millions of dollars. The reactor will never again operate as efficiently as it once did because the State has demanded that the cooling lake not be treated as such but as a natural recreational lake. This hearing is the beginning of proceedings aimed at applying to C- and K-Reactors and to the D-Area coal-fired powerhouse similarly costly and unnecessary changes. I ask the State of South Carolina, in the interest of responsible concern for the American people, to withdraw its demands and allow SRP to continue its efficient, safe and environmentally benign operations. Failing this, I ask the Department of Energy to take no action as its decision and defend it vigorously up through the courts, if necessary. Thank you very much.	

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
LETTER FROM MR. W. B. BEBBINGTON		
	Thank you for the opportunity to comment on the "Scoping of an Environmental Impact Statement on cooling-water systems at the Savannah River Plant."	Comments noted.
	It should be recognized at the outset that the important issues under consideration, here, are political and bureaucratic <u>not</u> environmental. There is, in the document [6450-01] that defines the purpose of the August 19 public meeting, no reference to past, present or potential future harm to the environment surrounding SRP caused by operations within it. The absence of such harmful effects has been documented in public reports of comprehensive routine and special scientific monitoring over the past quarter century of the plant's existence.	
	In 1950 about 200,000 acres of land was purchased by the United States government on which to build the Savannah River Plant. The large site was acquired to provide isolation of the production facilities and to ensure that those facilities would not harmfully affect surrounding private lands, and most importantly, not damage biologically the Savannah River. Accordingly, the facilities of greatest environmental concern, the reactors and separations plants, were sited near the center of the plant, several miles from the river and the boundary fences. The channels of insignificant streams that rise within the plant, streams that were not then, are not now, will not be in the future of any economic, recreational or unique ecological importance, were used to convey reactor cooling water to the river. The river was seen to be the most important natural resource that might be vulnerable to harm, and the Academy of Natural Sciences of Philadelphia under the direction of the eminent Limnologist, Dr. Ruth Patrick, was commissioned in 1951, years before plant startup, to monitor comprehensively the biological condition of the river. The work of ANSP continues, today, and Dr. Patrick has repeatedly and unequivocally stated that there has been no biological damage from the thermal effluents of SRP. Vegetation in the streambeds was damaged, to be sure, but not irrevocably as was shown by the recovery of Steele Creek during the years that L-Reactor was shut down.	
	The matters with which we are now concerned stem from the actions taken to refurbish and restart L-Reactor at SRP as	

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	authorized by Congress in 1980. Operation of the reactor was declared necessary by October 1983 to meet the needs of national defense. The Department of Energy was obliged to meet this goal. The reactor was rehabilitated and brought up to the technological state of the other operating reactors with the intent to operate it as it had operated for fourteen years, previously, and as two other reactors, K and C, were continuing to operate. Near the end of 1982, anti-nuclear activist groups abetted by State officials instigated a succession of delays and ultimately, through a bit of Congressional trickery, the requirement that the cooling water from L-Reactor be passed through a new 1000-acre lake enroute to the Savannah River. Ostensibly, this lake was to forestall damage to "wetlands;" in fact it will permanently inundate most of the area of concern and destroy much productive forest in addition. The direct cost of the lake was to have been \$25 million, but has risen to \$40 million. The overall addition to the national deficit and cost to the taxpayers, taking into account delays, interest charges and permanent productivity losses will be in the hundreds of millions of dollars, <u>with, on balance, a detrimental environmental effect</u>. If the reactor starts up in October, as is now hoped, it will have been delayed two years.	
	With regard to C and K reactors and the D-Area coal-fired power house, we are now at the point where the L-Reactor fiasco began more than three years ago. No existing environmental harm is alleged, only the need to comply with a "Consent Order" dated January 3, 1984, three decades after the beginning of safe, efficient and environmentally harmless operation of SRP. We taxpayers need to be protected against the squandering of more hundreds of millions of dollars merely to enhance the egos or further the special interests of politicians and activists.	
	It is stated on page 7 of the notice of this meeting that, "As required by the Council on Environmental Quality regulations for implementing the National Environmental Policy Act, the EIS will also consider 'no action'." I urge that "no action" be given first consideration and that the matter be shelved without even the preparation of another redundant, unnecessary and costly Environmental Impact Statement.	

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	STATEMENT OF MS. FRANCES HART ENERGY RESEARCH FOUNDATION	
	I am Frances Hart, and I represent the Energy Research Foundation. We appreciate the opportunity to address this hearing on the subject of the scope of the proposed environmental impact statement concerning cooling water systems for thermal discharges from the C- and K-Reactors and from the D-Area coal-fired power plant. The issue of environmental impacts of cooling water systems at SRP was discussed and analyzed at length as part of this NPDES permit reissuance process which began in 1982 and during the L-Reactor EIS process. A permit demanding compliance of the Clean Water Act requirements was issued by DHEC for SRP's operating reactors in January of 1984, along with the Consent Order allowing the continuation of direct discharge of cooling water for an unspecified time. DOE was required to prepare a comprehensive study of the impacts of thermal discharges and recommend alternative systems which would comply with the Clean Water Act. Nearly a year ago, in October of 1984, DOE published this report called "Thermal Mitigation Study, Compliance with the Federal and South Carolina Water Quality Standards," which analyzed various cooling water options. We reviewed that report and believe that recirculating mechanical draft cooling towers and once-through mechanical draft cooling towers with holding pond systems -- these are alternatives C-4, C-5, K-5, and K-6 -- would be acceptable for C- and K-Reactors. Although DOE is required to analyze all reasonable options during the EIS process, we would urge that any option chosen provide at least as much environmental protection as do these options. It may not have been clear as early as 1981, when these original NPDES permits for the operating reactors at SRP expired, that new cooling water systems would have to be installed. But this necessity must have become obvious soon thereafter when negotiations with DHEC over new permits began, and South Carolina's Attorney General ruled that SRP's streams were part of the state.	

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	It is unfortunate that the EIS process was not begun at that time and that these years have passed without implementation of some sort of mitigation. Beginning the EIS process now has the obvious side effect of delaying still further the long-awaited cooling systems. We believe that complying with the National Environmental Policy Act is a valuable objective and, therefore, that the delay is perhaps warranted, even at this late date.	
D-1	However, because it seems unlikely that substantive new information will be generated during further study of possible alternatives beyond that already offered in the L-Reactor EIS and NPDES comments, we would urge that the preparation of this particular environmental impact statement be expedited as much as is possible within the law, given the substantial information and public comments already generated in these other related processes.	The Department of Energy will expedite the preparation of the EIS to the extent permitted by its regulations for implementing the procedural provisions of the National Environmental Policy Act.
D-2	The EIS is designed to play an integral role in the decision-making process, a role which cannot be very meaningful after the fact. Hopefully, DOE will initiate the EIS process at the beginning of future projects as the law requires, rather than after extensive study has taken place and time has elapsed, to ensure that the process itself can be meaningful and that timely compliance with other legal requirements will be possible.	The preparation and completion of the Thermal Mitigation Study and Comprehensive Cooling Water Study were undertaken by the Department of Energy in fulfillment of and compliance with the Memorandum of Understanding and Consent Order with the State of South Carolina. The Department of Energy is currently undertaking the preparation of the environmental impact statement to fulfill its requirements pursuant to the National Environmental Policy Act--as identified in the current Consent Order with the South Carolina Department of Health and Environmental Control--in attaining compliance with South Carolina's Class B water classification standards.

Thank you.

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	STATEMENT OF MR. KARL HERDE	
	I am retired from the Atomic Energy Commission. I retired five years ago. I came here in 1951 as the first environmentalist for the Atomic Energy Commission. I served 23 years in that capacity; and, during that time, the emphasis always with the Atomic Energy Commission was with regard to the taxpayers' dollars. As a guardian of the taxpayers' dollars and a taxpayer myself, along with the few hundred million other taxpayers, I would like to say that we have had enough. The costs are just unjustified. I am also a member of the Antique Automobile Association of America. We have a motto there for antique cars: If they are not broke, don't fix them. Experience has proven that there is nothing wrong with the way the reactors have been operated out there at the Savannah River Plant. I want to completely endorse my friend Mr. Bebbington on what he just said in the second talk ahead of this one. I'm an environmental biologist by training and experience. I started my biological work with the Atomic Energy Commission back actually with Du Pont at the Hanford Plant in the State of Washington. There, I was a group leader in environmental biology for five years before coming here. When I came here, I came by way of Washington, in which they very definitely gave me the indoctrination that we are guardians of the taxpayers' dollars. We are to see that every dollar spent of government money is to get just as much value out of it as if it were our own dollars. That theory still should exist. I'm afraid it doesn't. We are willing to help build up the deficit by requiring costs that are unjustified. Earlier, we built nine big plants and completed the plants roughly in a square-mile area for less than 3 billion dollars. We have not come close to that now. Our liaison negotiations with the contractor, the Du Pont Company, were every thousand dollars that we could save was a thousand dollars earned for the government. Every \$100,000 was that much more.	

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	As an environmentalist, we look toward saving dollars. I still think that that should be the utmost concern in the plan and method of our Department of Energy. I have my reservations, but I think I should make this statement. I actually hope that our Congressmen are smart enough that they won't allow this expenditure. I know that the plant needs to go on and I know, from a biology standpoint, we need to be safe; but I'm an environmentalist. I am not a lobbyist. I am not an activist, but I certainly want the environment to be kept intact. Our authority back in the early days was respected authority. The three main authorities we had were the Reactor Safeguard Committee, the National Academy of Science, and the International Commission on Radiation Protection. We met the standards of those three organizations. We were doing a good job. Those three organizations are all made up of men of prestige. There were not would-be environmentalists, self-made environmentalists, in the group. They were all college-trained and college-experienced people, and those three organizations guided our destiny and guided well. Using our minor tributaries and streams was regarded by people who were looking after the taxpayers' dollars as good business, as good logic, as good empirical use of the streams. Our empirical experience over the past 30 years has proven that theory to be right. It's just as right now as it ever was. The streams have adjusted to the higher temperature, and to change them now is rather futile. One thing about the stream, though, a stream has its own capacity to restore itself. It doesn't need the restoration, the decontamination, and so forth that a cooling tower is going to take. A cooling tower can become a sight in the environment. I would like for some of you to take a trip up on the upper part of the Ohio River up in the region of West Virginia and Pennsylvania. Look along that river. There are a bunch of old, rusty monsters, towers, cooling towers, that have been completely abandoned and have been left there to become a part of the environment. I don't like that kind of an environment. I don't want to see that kind of environment on our Savannah River.	

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Comment number	Comments	Responses
E-1	I think we know that our streams will clean up themselves and will become fertile and productive biological streams within two or three years. In a very few years, a stream will produce good fishing again without any effort on the part of man. All he has to do is let mother nature take over. I want to say the pond costs us 40 million dollars and is killing off every species, every plant and animal species, of that thousand acres of land to save or maybe better the environment of one or two individual species. If that makes sense, I'm crazy. Now, the cooling towers will be the same thing. You will ruin more of the environment than you will correct by installing the cooling towers. So let's hope that our Congress takes the right action on that, and I think it should be up to Congress or a bill to be presented to our courts.	Chapters 2 and Chapter 4 of the EIS present and discuss both adverse and beneficial impacts of the cooling water alternatives considered.

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
STATEMENT OF MS. DORCAS ELLEDGE		
	I appreciate the opportunity to say a few words to you. I have been to many of the meetings concerning the L-Reactor and read as much as I could understand of the books relating to that.	
	I still compliment the Department of Energy for doing something about the L-Reactor, a better way than putting scalding water in a stream that would have destroyed life. I don't know the best way. I'm not an engineer, as I've said before.	
	I don't know the best way to cool the water and to restore life to these streams that have been killed by the scalding waters from the reactors now in operation. But I do feel that it is an obligation of the Department of Energy and any governmental agency to protect life as we know it on earth.	
	To do less and to do nothing in this case will eventually affect our life, and it might well put South Carolinians and Georgians and anyone else visiting this state on the endangered species list.	
	I do feel that South Carolina citizens and Georgians and all those affected by the operation of the Savannah River Plant deserve protection, equal protection, with all citizens in the United States.	
	I believe we make nuclear weapons to protect our safety. I believe the obligation also in the making of them is paramount with the United States Government.	
F-1	And I do urge you to pick the best solution to the problem that DHEC has required of you. To do nothing doesn't sound like a solution to me, and that is one of the alternatives.	The consideration in the EIS of "No Action" is required pursuant to regulations of the Council on Environmental Quality for implementing the procedural provisions of the National Environmental Policy Act (40 CFR 1500-1508).
	And I thank you very much.	

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
STATEMENT OF MS. JEAN ROBINSON ON BEHALF OF W. F. LAWLESS		
My name is Jean Robinson. I'm presenting a statement for Professor W. F. Lawless who had to be out of town at this time. Professor Lawless is at Paine College in Augusta, Georgia. The statement is entitled Scoping Comments on SRP Cooling Water Systems EIS. <u>General Comments</u> To proceed with some general comments, the Department of Energy should be commended for asking for public scoping comments on the proposed Savannah River Plant cooling water systems environmental impact statement. Compared to the recent public imbroglio between the South Carolina DHEC and SRP, wherein DHEC had cited SRP for groundwater violations, and as well to past coverups of SRP reports by the Department of Energy, it's always refreshing to have government business conducted in the open. However, as important as this is, it can be significantly improved.		
G-1	The public does not have the technical capability nor the time to adequately explore nor keep track of the rather abstruse scientific studies of the environmental interactions and alternatives explored in this new environmental impact statement. That the public knows of, there are two such SRP environmental impact statements now underway. A publicly funded peer review committee should be created, using regional scientific and political talent, as a means of safeguarding the public's interest. Both DHEC and DOE, by their nature as political bureaucratic institutions, have more than enough administrative chores to worry about as it is, and an independent peer review panel would appropriately monitor scientific reports and construction projects with the rigor that escapes bureaucracies. If a peer review panel prevents the necessity of another 60-million-dollar clean-up similar to that now being spent to clean up the M-Area seepage basin fiasco, such a peer review panel could easily afford to attract talented participants. The public deserves more than playing DHEC against DOE to protect its interests and the environment. As the technological stakes increase, an independent scientific peer review panel	As required by the regulations of the Council on Environmental Quality (40 CFR 1502.19), copies of the draft EIS will be provided to Federal and State agencies having special expertise with respect to any environmental impact that might be involved.

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	for the Savannah River Plant will add flexibility, improve technological solutions, and reduce the opportunity for environmental impacts, mistakes, and ineptitude. This technique has worked well with the NASA bureaucracy, and landed Americans on the moon. On the other hand, without peer review panels, the SRP has given us not only the M-Area seepage basin, but 67 other seepage basins at the Plant as well.	
	<u>Specific Comments</u>	
G-2	1. The DOE has not yet responded to information provided at the last Public Scoping Meeting on the reported statistically significant differences between strontium-90 concentrations found in milk around the SRP plant compared to the Southeastern average concentration of strontium-90 in milk.	Responses to comments received during the scoping period for the preparation of the environmental impact statement on waste management activities for groundwater protection will be included in that environmental impact statement.
G-3	2. The new EIS should consider treatment of the cooling water before it is released back to the environment.	The effluent from the cooling systems considered in the EIS will meet the State of South Carolina's Class B water classification standards. The effluent is expected to be similar to the water quality of the Savannah River, and other than for reduction of temperature, treatment of the cooling water will not be required.
G-4	3. Water quality analyses of water released into the environment from C- and K-Reactors and the D-Area coal-fired power plant should be published and compared to EPA drinking water standards. The D-Area basin overflow and outfall water quality characteristics should also be provided.	Water quality impacts of the alternatives will be assessed in Chapter 4 of the EIS.
G-5	4. The D-Area power plant air quality at the release point from its cooling tower should be included in the new EIS.	Air quality impacts of the alternatives for the D-Area powerhouse will be described in Chapter 4 of the EIS.
G-6	5. P-Reactor effluent, that is, thermal, water quality, air stream quality characteristics should be included in the new EIS. Also, a biological community comparison to Par Pond with a comparable sized pond to Par Pond should be made and included. An aquifer water quality analysis of water under Par Pond should be made and included in the proposed EIS.	A discussion of P-Reactor effluent and Par Pond is not within the scope of this EIS, as discussed in the <u>Federal Register</u> notice announcing the preparation of the EIS.
G-7	6. The South Carolina DHEC and DOE March 1985 agreement suggests the continued use of a raw water basin at the D-Area power plant. The advantages of having a lined basin and an unlined basin, as well as RCRA compliance, should be discussed in the new EIS for this basin and for the ponds at C- and K-Reactors.	The use of the raw water basin at the D-Area powerhouse does not involve hazardous waste; therefore, a discussion of having lined basins and compliance with RCRA is not an appropriate topic for inclusion in the EIS.

Table H-2. Scoping Comments and DOE Responses

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G-8	7. Water quality characteristics of the cooling water at its source should be provided. Coolant waste system diagrams and effluent system diagrams should be provided. Well construction and closure information as necessary should be provided.	Chapter 3 of the EIS will describe the existing surface-water hydrology and water quality of the streams that would be affected by the alternative cooling water systems. Also see the response to comment G-3. If well closures should be required due to construction of the alternative cooling water systems, the closure wells will be discussed in the EIS.
G-9	8. Cooling water tower effluent characteristics at the release point should be provided.	See the response to comment G-3.
G-10	9. All mathematical models should be detailed, statistical techniques discussed, and validation of all models, equations, or techniques discussed. Thank you very much. That concludes his statement. And he wanted to let you know that he would be glad to submit a final copy by the 31st but wishes to make you copies of this because of some typographical errors.	Appendix B of the EIS and its referenced documents will discuss the models, assumptions, and validation of models used in the preparation of the EIS.
ADDITIONAL COMMENTS CONTAINED IN LETTER FROM W. F. LAHLESS DATED AUGUST 29, 1985		
G-11	No. 10, Airborne releases, including levels of dioxin, from the Beta-Gamma Incinerator (BGI) at the point of release should be quantified and reported. Provide calculated and actual release data, <u>from the point of release</u> , for each waste category, matching the BGI incinerator burn loads to normalize the predicted with actual data.	A discussion of airborne releases from the Beta-Gamma Incinerator is outside the scope of this EIS.
G-12	No. 11, The two high level radioactive waste (HLW) corrosion pitting reports (L-Reactor EIS, p. M 113-114) did not discuss corrosion pitting in HLW tanks 25-28. These 4 HLW tanks were not treated for corrosion pitting as were HLW tanks 38-51, since HLW tanks 25-28 were already radioactive when the corrosion pitting was discovered in the 14 HLW tanks completed later. Provide a corrosion pitting status report on HLW tanks 25-28 performance, and compare to the last 14 HLW tanks at SRP (tanks 38-51) that went into radioactive waste service after remedial action for corrosion pitting.	A discussion of high-level waste is outside the scope of this EIS.

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Comment number	Comments	Responses
	STATEMENT OF MR. SAM SCHILLACI	
	I've been studying the Savannah River Plant for a long time, and I've got a good plan for its survival. I'm a former employee also with ten years of service with the Department of Energy. I had some mental problems because of stress, so the government "retired me." The stress was brought on because I didn't like all the waste, fraud, and abuse out there. But they dumped me in a hurry. For six months after they dumped me I went without a salary or any means of support. I had a lot of time to think, do things I've never done before, drink a lot, write, which I thoroughly enjoy, even though my grammar ain't so hot. Now, my plan for DOE is simple. It's the same (expletive deleted) plan I had. Set all the DOE employees, and hopefully all the government employees, free at a certain, hopefully surprise, moment. They all go home for five months without leave or salary. They could think, read, do anything they want to. They could grind and gnash their teeth if they want to. And at the end of the five-month period -- notice that I give them a little less time than I had; I'm lenient -- the ones that haven't done themselves in could come back and determine if those cooling ponds or whatever is needed out there at SRP. Let them think a little more. Now, if the government employees do that, I think the whole public sector would probably do the same thing. Just think of all the fun that we could have. 1929 all over again. Mr. Herde, you probably remember him. That's probably why he has grayer hair and his voice has a little more common sense in his tone of voice. And just think of all the neat movie stuff of 1929. Back to the future. Anyway, I'm not anti or pro nuclear or anything; I'm just pro myself, pro my God, which is different from your God, and a survivor. I hope more become self-reliant, learn to fight rather than this (expletive deleted) love we have now, and learn that the best plan is no plan. I will also shut up my mouth for a half million dollars, passage to New Zealand, and permanent silence to the Will Rogers Institute. After five months I hope the hot water is used for enemas for anybody who wants it. Thank you.	Comments noted.

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Comment number	Comments	Responses
STATEMENT OF MR. WILLIAM McDANIEL		
	I have no written speech with me, but I do have a part of a tape that I would like to play. Of course, you can have a copy of the tape.	
	I think you are escalating out of control as far as reactors are concerned. This has very little bearing, I realize this, on the coolant system that you have here as far as water going back into the creeks and rivers and so on. I would like to play as much of this tape as I can. I appreciate this opportunity.	
	(Mr. McDaniel began playing the tape.)	
	Forbes, the magazine that calls itself a capitalist tool, last month proclaimed on its cover the failure of the U.S. Nuclear Power program ranked as the largest managerial disaster in business history. Forbes pointed out that we spent more on nuclear power than we did on the space program or the Vietnam War, and the magazine says, "Only the blind or the biased can now think that most of the money has been well spent."	
	Well, that's something that Amory and Hunter Lovins have been saying for years. They are husband and wife who put their energies together to create a vision of a non-nuclear energy future.	
	"Who would have guessed that a beer-drinking, country-music-loving cowboy would team up with a scrawny, four-eyed, physicist?"	
	The physicist and the cowboy, she is also a lawyer and political scientist, were married in 1979. They began traveling around the world, as Amory says, "Cross-pollinating the energy grapevine." They wrote books and consulted for governments and businesses in 15 countries.	
	They contend that the new nuclear plants will turn out more electricity than we really need at a cost no one can afford and that the money the utility companies spend on those plants would be better spent on helping the country become more energy-efficient. In other words, use the money to help make homes, factories, and office buildings do the same work with less energy. Then everybody is a winner. The answer can be as	

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	simple as installing better windows, designing better buildings and appliances. At their home and research institute in Old Snowmass, Colorado, Amory and Hunter Lovins live their state-of-the-art ideas for saving energy. They built a 4,000-square-foot home, office, and indoor farm that takes the simple idea of a solar green-house and makes use of it on a grand scale. The 16-inch-thick curving walls provide more insulation than most people's roofs. The Lovins moved into the still-unfinished structure in January 1984. Soon after, they published a visitors' guide. More than 2600 people from around the world have to come to see their house. "This is the space we donate as the headquarters of our non-profit group, Rocky Mountain Institute, where we and about a dozen colleagues try to foster the official use of resources." Amory and Hunter Lovins use electricity for those things it does best. "Using nuclear power to heat a house," Amory Lovins has said, "is like cutting butter with a chain saw." Passive solar design, even at an altitude of 7100 feet in the Rocky Mountains, allows the Lovins to heat with sunlight year-round. "This is the greenhouse?" "No. This is basically the furnace of the house. These windows are, I think, the most advanced in commercial use anywhere. They insulate twice as well as typical shades and cost less. There is an invisibly thin film of plastic with special high-tech coatings on it which let the light in but don't let the heat get out, and then we fill up the space around that heat-mirror form with argon gas which insulates better than air." "Design with nature," say the Lovins, who would have built differently in a different climate; but some of their basic design elements are just common sense. If you insulate more, you have to heat or cool less. "There is about yea much polyurethane foam up on the roof, and there is 4 inches of it in the middle of the walls. Just (knocking sound) like that, and the house is also darn near airtight. We then laid it through what are called air-to-air heat exchangers."	

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	In all over the house, they have energy-efficient light bulbs. "It's an 18-watt bulb that screws into a regular socket and gives the same amount of light as a regular 75-watt bulb, so it's four times as efficient, lasts about thirteen times as long, and I think gives better light. It isn't a fluorescent folded up in there." The bulbs currently retail for \$18 to \$25 each. They are just coming onto the American market. Lovins' critics say that the bulbs are too expensive, won't fit in many home lighting fixtures, and are better for commercial lighting because they don't give full light instantly. Lovins also sees the benefits of commercial use, but he is not bothered by the warm-up time. He believes the price will come down and that the fixture problems will be solved. (Mr. McDaniel stopped playing the tape) I'm a member of two different groups, ecology groups. Of course, I'm a public citizen. The point I'm trying to get across is that, as I have stated here when I first came up here, things, in my opinion, are escalating out of proportion. Sometimes I think we should try to go back and erase the board and start all over, but then that cannot be done.	
I-1	I am still opposed to any type of radiation in regards to how high a level or how low a level it is, and I know we have certain amounts of radiation naturally. I think we have 82 percent of the oxygen that comes out of the Amazon Rivers in the New Guinea. But you add radiation onto x-rays that a person has had and nature itself, and then you are doubling and tripling it. The thing that bothers me most, which I see from research, is it's a mortality. You know the group I'm with. This is a research committee. It's a citizens' committee, and now we have taken a survey on mortality and cancer. I was so shocked when it went through my neighborhood. At least one or both people have died from cancer of some sort or the other, and the people around us are dying. I live on 2910 Carolina Avenue. Other members of this same group --	A discussion of the existing radiation environment at and in the Savannah River Plant Region will be presented in Chapter 3 of the EIS. Chapter 4 of the EIS will discuss the radiological impacts of the cooling water alternatives considered.

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Comment number	Comments	Responses
	(Mr. McDaniel's time for making his presentation expired)	
	Thank you. I appreciate it very much. I will see that you get a copy of the tape.	

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Comment number	Comments	Responses
STATEMENT OF ZOE G. TSAGOS LEAGUE OF WOMEN VOTERS OF NORTHERN BEAUFORT COUNTY The League of Women Voters of Northern Beaufort County appreciates this opportunity to participate, by our comments, in the preparation of an EIS on the type of cooling-water systems to be used for the C- and K- Reactors and the D-Area coal-fired power plant at the SRP. It is our understanding that a conditional National Pollutant Discharge Elimination System (NPDES) permit was issued to DOE for SRP by SCDHEC in January 1984. Compliance with NPDES provisions rests upon the issuance of an EIS which will note the environmental impact of thermal discharges from the above mentioned reactors and power plant and will outline the means proposed to mitigate the high temperature flow by the use of cooling systems so that the 90°F required by law can be attained before it reaches the Savannah River.		
J-1	Inasmuch as SCDHEC, according to the DOE statement on page 5 of the "Intent to Prepare an Environmental Impact Statement" document [6450-01] which we have received, has accepted either a cooling water system of "once-through cooling towers for C- and K-Reactors" or "recirculating cooling towers" as satisfying NPDES provisions, we support this SCDHEC position. We hope that DOE and SCDHEC will work towards whatever method is environmentally safest in thermal effluent management. An expedited EIS will help to bring this about with the least loss of time. We agree with Ms. Frances Hart in her presentation for the Energy Research Foundation at the August 19 DOE hearing in Aiken where she stated that if an alternative method is chosen, it should provide "at least as much environmental protection" as the SCDHEC acceptable cooling methods as presented above.	See the response to comment D-1.
J-2	We in Beaufort are as concerned as we have ever been about the quality of our drinking water which has as its source the Savannah River. We shall read with great interest the EIS analysis of "Environmental Issues" (p. 9) numbers: 6. "Radionuclide remobilization" and 9. "Cumulative thermal effects." Both changes can have an impact on the quality of downstream drinking water. In conclusion, we urge DOE to continue holding hearings in Beaufort as well as Aiken. The number of people attending any	Radionuclide remobilization and cumulative thermal effects will be assessed in Chapter 4 of the EIS for the cooling water alternatives.

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	one hearing has varied; this is perhaps also true of Aiken. Because the decisions reached and changes made at SRP are of great environmental importance to us here, we must continue to be involved and to actively participate in hearings held in Beaufort. Please include this submission in the Scoping Record.	

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Comment number	Comments	Responses
	STATEMENT OF ROGER L. BANKS U.S. DEPARTMENT OF THE INTERIOR FISH AND WILDLIFE SERVICE We have reviewed the above-referenced notice as presented in the <u>Federal Register</u> on July 29, 1985. The following comments are provided to you in accordance with the Fish and Wildlife Coordination Act and are intended to assist you during the preparation of the EIS.	
K-1	The environmental issues identified in the <u>Register</u> that you intend to analyze during the preparation of the EIS appear generally inclusive of the fish and wildlife resource issues of concern to the Service. It appears likely at this early stage in project planning that significant beneficial effects on wetland fish and wildlife resources will likely result from installation of the proposed cooling water alternatives. It also appears probable that significant adverse effects may result from siting of the cooling towers, holding ponds, and ancillary facilities.	The potential environmental effects resulting from the location of cooling water systems and ancillary facilities will be discussed in Chapter 4 of the EIS.
K-2	We would like to see the following issues emphasized and the extent of their probable effects quantified during subsequent studies: 1. The effects of reduced thermal effluents on fish and wildlife resources in the receiving streams and contiguous wetland habitats. 2. A comparison of habitat impacts resultant from alternative facilities siting plans. 3. Impingement and entrainment effects on fishery resources resultant from alternative plans.	Chapter 4 of the EIS will present the environmental consequences of the construction and operation of alternative cooling water systems, including the beneficial and adverse impacts to fish and wildlife resources, wetland habitats, and impingement and entrainment. Also see the response to comment K-1.
K-3	We recommend that the Habitat Evaluation Procedures (HEP) be considered as a means of comparing and quantifying the habitat effects of alternative plans considered in the EIS. Use of the HEP in this case could make economical use of the basic	A HEP study is being conducted to identify the value of habitat to be gained or lost for use in assessing further mitigation. The EIS will discuss the HEP study in Chapter 5.

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	framework of the ongoing L-Reactor HEP Mitigation Study. As a result of the L-Reactor HEP Study you have trained and experienced staff members capable of conducting a study within the time constraints of the EIS. In addition should the need for habitat mitigation be indicated after selection of the preferred alternative, HEP provides a means of mitigation cost-benefit analysis. Finally, the primary benefit of the HEP is in promoting interagency cooperation resulting in balanced planning decisions.	
	If you have any questions regarding our comments contact me at your convenience.	

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
STATEMENT OF J. W. MORRIS		
	Thank you for the opportunity to comment on the scope of the planned Environmental Impact Statement (EIS) on the Savannah River Plant (SRP) Cooling Water Systems. I urge that the EIS deal carefully and thoroughly with a cost-benefit analysis of the construction and operation of the proposed cooling-water systems. Specifically, the following aspects should be considered:	
L-1	1. The complete and continuing cost to the taxpayers of increasing the national debt to pay for, a. the proposed construction, b. the operational costs, - and c. the increased production costs that will result from the proposed operating limits. 2. The benefits, if any, that can be expected from the proposed changes.	Chapter 2 of the EIS will present the estimated costs associated with the cooling water alternatives considered. Chapter 2 of the EIS will summarize and Chapter 4 will discuss the adverse and beneficial impacts of the construction and operation of the cooling water alternatives.
L-2	I urge also that the EIS review the overall environmental productivity of the SRP site, as a whole, and compare that productivity with the productivity that might have been expected from the SRP area had the project been located elsewhere, and with the incremental effects that may be expected from the proposed cooling-water systems. Such a review will show that the environmental productivity of the SRP site now is very high, and that the incremental benefits of the proposed actions are very low. The long-term costs of the proposed action will be very high to the nation's taxpayers, the benefits will be very small, and none of these benefits will accrue to the public since the SRP site is necessarily closed to the public. The basic intent of the Clean Water Act and of Water Quality Standards is to protect the public and to preserve environmental productivity. At SRP overall the public is presently well protected and environmental productivity is very high.	Chapter 3 of the EIS will discuss the existing environment at the SRP site that will be affected by alternative cooling water systems, and Chapter 4 will discuss the environmental consequences of constructing and operating the systems. Since the cooling water systems will neither affect the entire SRP site nor can the systems be located elsewhere, the comparison of overall productivity as cited is considered outside the scope of the EIS.

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	I urge the Federal government to exercise its responsibility to the total spectrum of U.S. taxpayers, and to pursue all possible means to implement "No Action" in the matter at hand.	

Table H-3. Scoping Topics and EIS Sections

Comment number	Scoping topic	EIS section
A-1	Environmental impacts	Ch. 4, App. F
A-2	Environmental impacts	Ch. 4, App. F
A-3	Cooling water alternatives	Ch. 4
B-1	Regulatory requirements	Ch. 2, Ch. 4
D-1	Regulatory requirements	Ch. 1, Ch. 5
D-2	Regulatory requirements	Ch. 1, Ch. 5
E-1	Environmental impacts	Ch. 2, Ch. 4
F-1	Cooling water alternatives, No-action alternative	Ch. 2, Ch. 4
G-1	Regulatory requirements	Ch. 1
G-2	Scoping comments	Ch. 1
G-3	Water quality impacts	Ch. 4
G-4	Water quality impacts	Ch. 4
G-5	Air quality impacts	Ch. 4
G-6	Regulatory requirements	Ch. 1
G-7	Raw water basin usage - RCRA compliance	Outside the scope of the EIS
G-8	Surface water hydrology and water quality, well closures	Ch. 3, Ch. 4
G-9	Water quality impacts	Ch. 4
G-10	Mathematical models	App. B, App. G
G-11	Beta-Gamma incinerator	Outside the scope of the EIS

Table H-3. Scoping Topics and EIS Sections (continued)

Comment number	Scoping topic	EIS section
G-12	High-level waste	Outside the scope of the EIS
I-1	Radiological releases	Ch. 3, Ch. 4
J-1	Regulatory requirements	Ch. 1, Ch. 5
J-2	Radionuclide remobilization, cumulative thermal effects	Ch. 4
K-1	Facility siting impacts	Ch. 4
K-2	Fish and wildlife resource impacts	Ch. 4
K-3	Habitat impacts	Ch. 4
L-1	Cost of alternatives, impacts of alternatives	Ch. 2, Ch. 4
L-2	Affected environment, impacts of alternatives	Ch. 3, Ch. 4

APPENDIX I

POTENTIAL APPLICATIONS FOR UTILIZATION OF WASTE HEAT FROM K- AND C-REACTOR COOLING WATER DISCHARGES

During the public comment period on the draft environmental impact statement (EIS) for alternative cooling water systems at the Savannah River Plant (SRP), the U.S. Department of Energy (DOE) received several comments that requested consideration of other alternatives for use of the cooling water effluents from K- and C-Reactors. These comments did not identify specific alternatives (i.e., concepts with specific functions and features) for the effluents, but rather suggested that DOE consider the use of the cooling water or the contained thermal energy in agricultural or aquacultural applications or in the production of ethanol.

This appendix discusses earlier waste heat utilization studies conducted at the Savannah River Plant, and assesses the general alternatives identified during the public comment period (irrigation, soil warming, greenhouse heating, aquaculture, and ethanol production).

I.1 K- AND C-REACTOR COOLING WATER DISCHARGES

K- and C-Reactor each discharge approximately 11.3 cubic meters of reactor cooling water per second at an average temperature of between 70°C and 77°C. These discharges are not continuous; periods of reactor operation depend on production runs and on required maintenance shutdowns of 1 to 2 months, which generally occur during the summer. The chemical quality of the cooling water is similar to that of the Savannah River; however, the cooling water from both reactors contains tritium, a radioactive isotope of hydrogen, resulting from small process water leaks in the reactor heat exchanger.

I.2 PREVIOUS STUDIES

DOE has funded or performed several studies that evaluated the potential for utilization of waste heat generated at SRP. In 1978, the South Carolina Energy Research Institute (SCERI) prepared a report entitled Low Level Waste Heat Utilization Project, Savannah River Plant, Preliminary Analysis. This study considered a number of potential waste heat utilization projects, including agricultural and aquacultural uses, industrial applications, and direct power generation. It evaluated five agricultural options - soil warming, biomass production, greenhouse heating, anaerobic digestion of animal wastes, and space heating of poultry brooding houses. After the evaluations, the researchers did not consider any of these options to be independently viable as a major user of SRP waste heat. Of the nine aquatic species evaluated for potential commercial culture using SRP waste heat, the report considered the culture of freshwater prawns and channel catfish to offer the most promise as an end user in an energy cascade system. Of the direct power generation options considered, a Rankine cycle system appeared to be the most viable.

In 1982, Clemson University's College of Agricultural Sciences and College of Forest and Recreation Resources prepared a report entitled Feedstock Options for Ethanol Production at the Savannah River Plant (Cross et al., 1982). This report provided DOE with information to judge the short- and long-term potentials for feedstock alternatives for onsite ethanol conversion.

In 1983, Arthur D. Little, Inc. (ADL), under contract to E.I du Pont de Nemours and Company (Du Pont), prepared the SRP Cogeneration Study, which evaluated the feasibility of various methods of cogeneration (i.e., the recovery and utilization of heat from the reactor effluents) as a means of reducing SRP thermal impacts. The ADL investigation utilized the previous studies conducted on this issue with appropriate updates of technologies and costs (ADL, 1983). The cogeneration options evaluated included the generation of electricity using Rankine cycle systems, the generation of process steam for the SRP using heat pumps, onsite industrial applications (direct uses and/or temperature augmentation using heat pumps), onsite agricultural and aquacultural applications, and hot water delivery to offsite users. ADL evaluated each of the applications with respect to technical, economic, institutional, and environmental feasibility. The environmental evaluations included an assessment of the ability of the cogeneration options to meet the proposed 32.2°/2.8°C thermal standard for SRP streams. This standard requires that the temperature of plant effluents entering a natural stream not exceed 32.2°C, and that plant effluents cause no more than a 2.8°C temperature increase above the natural stream temperature.

ADL evaluated the onsite applications both as standalone strategies and as precooler strategies. The standalone evaluations examined the cost/benefit associated with adding a cogeneration system to the existing once-through reactor cooling system. The precooler evaluations assumed that the once-through system would be augmented by mechanical-draft cooling towers, and examined the cost/benefit of using cogeneration to precool the reactor effluent before it enters the cooling towers.

Based on a detailed review of the ADL work and on an independent assessment of cogeneration, the Savannah River Laboratory (Roggenkamp, 1983) concluded that none of the standalone strategies would provide sufficient temperature reduction to satisfy the 32.2°/2.8°C thermal standard for SRP streams year-round. The precooler strategies were not considered feasible for reasons specific to each application, as discussed below.

Technically, Rankine cycle systems could generate as much as 37 to 46 megawatts of electricity at each reactor. However, while the 12°C temperature reduction would permit the use of smaller cooling towers, the delivered electricity costs would be 2 to 3 times higher than the costs for the current system of purchased electricity.

The only technically viable heat pump application identified in the studies would result in a decrease in reactor cooling water effluent temperatures of only 0.6°C. In addition, this application would be uneconomical.

Onsite industrial, agricultural and aquacultural applications, and heated effluent delivery to offsite users would not be feasible because of poor economics and many institutional barriers.

The institutional problems associated with industries locating to the SRP area to obtain low-cost heat from the reactor effluent would be virtually insurmountable. ADL cited the problems encountered by the Tennessee Valley Authority in attracting industries to use the waste heat from its Watts Bar Nuclear Power Plant.

The ADL study concluded that onsite agricultural and aquacultural uses of the waste heat were not feasible. Features of these applications leading to poor economics are the relatively low duty cycle (heat generally not needed except in winter) and the relatively low value of the output. Also, the study determined that, unless very large land areas are employed, these applications would produce little impact in terms of waste heat utilization. The relatively frequent outages of the reactors also would cause difficulties with respect to winter kill unless backup systems were provided. In addition, Federal legislation [21 USC 321(s) and 342(a)(7)] expressly forbids the adulteration of food or food products with any radioactive substance. SRP reactor cooling water contains tritium as a result of small process water leaks in the reactor heat exchangers. While discharges of this radioactive material are well within applicable regulatory limits for water quality, the legislation regarding food and food products sets no lower threshold limit, precluding the use of this water for direct contact use in agriculture or aquaculture.

The study also concluded that it would be uneconomical to pipe reactor cooling water effluent offsite for district heating or industrial applications.

I.3 POTENTIAL AGRICULTURAL APPLICATIONS

I.3.1 IRRIGATION

This potential application for the utilization of SRP waste heat would entail delivery, via a closed pipeline or open canals, of reactor cooling water effluent to offsite users for direct contact irrigation of agricultural crops.

In the six-county area surrounding the SRP, agriculture accounts for approximately 21 percent of the total land use (DOE, 1984). The results of the 1980 census of population (Bureau of the Census 1982a,b) indicate that fewer than 2 percent of the population in the six-county area were employed in the category of agriculture, forestry, and fishing, a 2-percent decrease from 1970. Agricultural land in the six-county area is undergoing a transition from smaller operators to larger consolidated farms, especially in the rural areas of Allendale, Bamberg, and Barnwell Counties (DOE, 1984).

Although the conservation of water resources is considered a national priority and recent drought conditions in the southeastern United States have generally indicated the importance of the availability of adequate water supplies, DOE is not aware of specific agricultural needs or requirements for diversion of existing water resources for use in the irrigation of local crops. No uses of the Savannah River for irrigation have been identified in either South Carolina or Georgia (Du Pont, 1982).

Even if a specific need was identified for local use of the SRP reactor cooling water for irrigation purposes and recognizing the legal barrier for

such uses for food crops described above, various environmental, technical, and economic difficulties exist; these are discussed below.

The estimated temperature of the cooling water delivered from K- and C-Reactors to an offsite location would be between 52° and 75°C. Before it could be used for irrigation, this water would have to be cooled to about 32.2°C to avoid damage to crops. In the summer, when irrigation is needed and the ambient Savannah River temperature is approximately 26°C, an estimated 156 cubic meters per second of local water (or seven times the amount of cooling water delivered from K- and C-Reactors) would be required to dilute and thus cool the discharge water from both reactors to 32.2°C. This quantity is equal to the 7-day, 10-year low flow (159 cubic meters per second) of the Savannah River near the SRP. If such quantities of local water were available, the K- and C-Reactor discharges probably would not be needed for irrigation; because this amount of local surface-water use is not considered feasible, a cooling system (i.e., once-through or recirculating cooling tower) would still be necessary to cool reactor cooling water sufficiently for irrigation use. In addition, during those periods when irrigation water would not be required, some alternative mechanism of cooling water disposal (and cooling to meet regulatory requirements) would be necessary.

The offsite agricultural user(s) would be responsible for meeting all construction and operational permit requirements for offsite irrigation systems. Major issues of concern from a regulatory point of view relate to large volume translocation of a riverine water resource to the groundwater table and the potential permit requirements of transporting surface water from one basin to another (for example, interbasin transfer from the Savannah River basin to the Salkehatchie River basin near Allendale, South Carolina).

To deliver heated water from K- and C-Reactors to a potential user(s) at the SRP boundary line, DOE would have to construct either open canals or an underground pipeline. Consideration was given to the use of open cement-lined canals with gravity flow, similar to those constructed to carry cooling water from the P- and R-Reactors to Par Pond. However, this alternative was considered less attractive than the closed pipeline option for both technical and economic reasons. Several stream valleys and ridge lines would have to be crossed between the reactors and the SRP eastern and western boundary lines. Gravity flow canals could only be used from a ridge line to the next stream valley, from which a closed pipeline and a pumping station would be required to move the water to the next ridge line.

Water flow in a canal would be by gravity, whereas the pipeline would be under pressure from the pumps. Therefore, the pipeline could use a shorter, straight path and follow the existing ground elevation to avoid deep excavations and fills. A canal would have to meander along the contours, requiring a longer route and greater expense. The canal would also produce a larger potential area of disturbance than the pipeline and, accordingly, would have a greater potential environmental impact.

A pipeline system would require the following:

- A pumping station at each reactor with underground reinforced concrete pits approximately 20 meters deep, each containing 10 pumps capable of pumping 2.3 cubic meters per second.

- Associated control buildings, valves, electrical substations and switchyards, and access and security facilities.
- Underground pipelines from each reactor area to the SRP boundary. Each pipe would be about 2.5 meters in diameter. Both pipes would be combined into one about 3.7 meters in diameter where the lines converge. The system would have drain and air valves at low and high points in the pipes, similar to those in existing wastewater pipelines.

A pipeline could follow several routes from K- and C-Reactors to the SRP boundary. The closest point on the boundary to either reactor is along the Savannah River. However, no practical use exists for heated water in this area because it consists almost exclusively of wetlands. The route to a usable offsite area with the shortest total length of pipe (Figure I-1) would start at a new K-Reactor pump station and follow the existing 115-kilovolt transmission line and control cable between K- and C-Reactors for about 4.5 kilometers. A 0.5-kilometer pipeline would run from the new C-Reactor pump-house to connect to that pipeline just north of Road 3. From this connection, a larger combined pipe would follow the existing South Carolina Electric and Gas (SCE&G) Company transmission line to the intersection of Roads 2 and C. From this point, the pipe could either continue along the transmission line or run parallel to Road C to the SRP boundary near Jackson, South Carolina. The length of the large pipe would be about 13 kilometers, and the total length of pipe would be about 18 kilometers.

A second possible route (Figure I-2) would have the small pipes run from each reactor to a junction at the intersection of Roads B and C near L-Reactor. From the new pumphouse at C-Reactor, the pipe would follow the C-Area railroad to Road C, and then parallel Road C to the junction; this pipe would be about 8.5 kilometers long. The pipe from K-Reactor would run parallel to Road B for about 5.5 kilometers. From this junction, a larger pipe could follow two routes to the boundary. The shorter route (Route 2-A) would turn south, cross Myers Branch and the Seaboard Coast Line Railroad, and run approximately parallel to the SCE&G transmission line for about 10.5 kilometers to a point on the SRP boundary near the northwest corner of Allendale County. This point is near a ridge line that bisects the area between SRP and Lower Three Runs Creek. The large pipe could also continue (Route 2-B) from the junction 14 kilometers along Road B to the SRP boundary east of Par Pond. This point is near a ridge line that runs south through part of Barnwell County and most of Allendale County between Lower Three Runs Creek and the Salkehatchie River. The total lengths of pipe for Routes 1 and 2 are 24.5 and 28 kilometers, respectively.

Although the route to Jackson is the shortest, the pumps at each reactor would have to be larger than those required for the other routes because the pipeline would reach its lowest point where it crosses Upper Three Runs Creek; the system would have to pump water upgrade to the boundary. Stream crossings on the other routes are at higher elevations.

Depending on the pipeline route selected, 1200- to 1800-horsepower motors would power the pumps. The rating for each pump would be 1.1 cubic meters per second and the required power supply per pump would range between 0.995 and 1.5 kilowatts. Because each pumping station would require 10 operating and

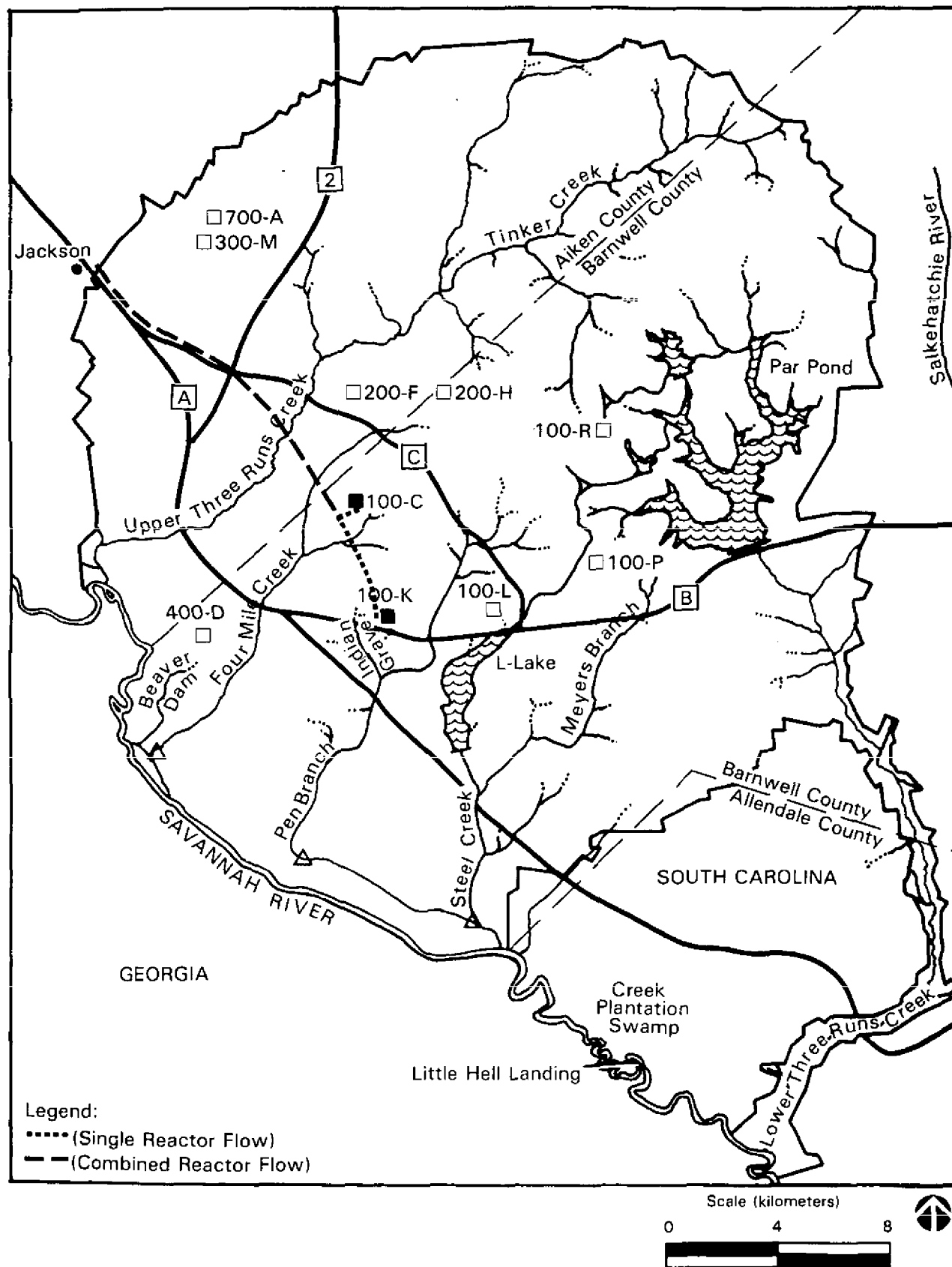


Figure I-1. Proposed Pipeline Route 1 (West)

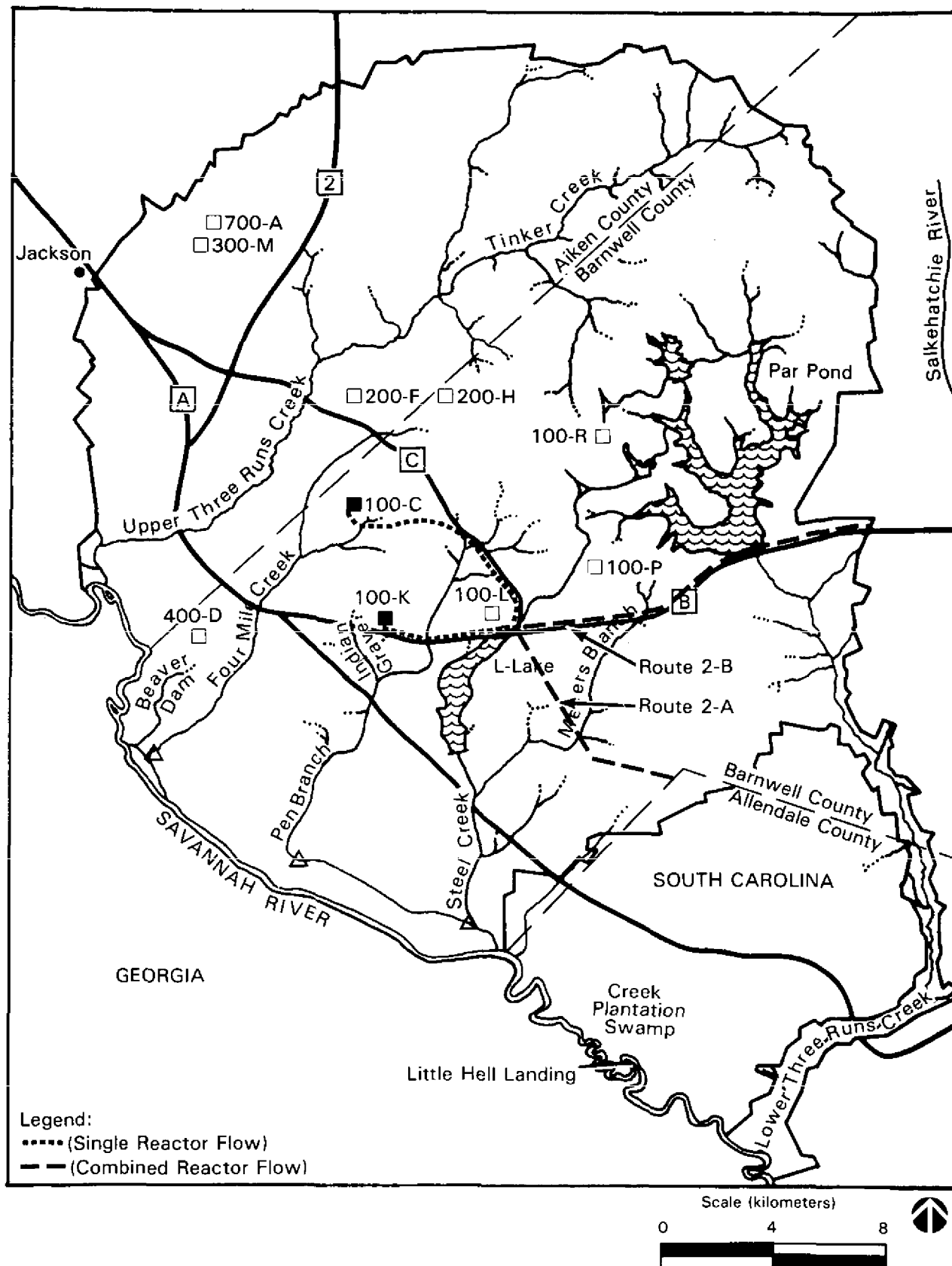


Figure I-2. Proposed Pipeline Route 2 (East)

5 redundant pumps, DOE would have to construct an electrical power substation and special transmission lines. The estimated total DOE construction costs for pumping stations and pipelines range between \$188 and \$215 million, and the estimated annual operating costs would be approximately \$18 million (Table I-1).

Table I-1. Costs for Closed Pipeline to Carry K- and C-Reactor Cooling Water Offsite

Item	West pipeline (Figure I-1)	East pipeline (Figure I-2)
Length of route (kilometers)	24.5	28
Capital costs (\$ million)		
Pipeline	44	64
Pumps and accessories, installed	92	92
Contractor operations and profit	27	31
Design	25	28
Total capital costs (\$ million)	188	215
Operating costs per year (\$ million)		
Power (at \$.06/kWh)	13	13
Operations and maintenance	5	5
Total operating costs per year (\$ million)	18	18

DOE estimates that it would require about 12 to 15 months to design the pipeline, and about 24 months to construct the shortest system or 32 months to construct the longest route. The workforce is estimated to be 25 personnel for operations and 15 for maintenance.

I.3.2 SOIL WARMING

Warming of crop soils to higher temperatures during the cooler months has been tested experimentally as a method of increasing agricultural productivity. SCERI (1978), in its assessment of potential applications at SRP, reported on soil warming experiments that produced a variety of effects on growing crops: longer growing seasons, higher quality vegetables, and sometimes significant increases in yields. However, artificial warming of the soil has also been found to cause substantial reductions in yields of some crops. A system using waste heat to provide soil warming would include the following necessary components:

- The availability of land suitable for crop production

- Sufficient labor, management, and equipment to produce a crop
- An extensive system of buried pipelines for the transfer of heat to the soil
- An irrigation system to alleviate the increased evapotranspiration caused by higher soil temperatures

Temperatures higher than 32.2°C have been found to decrease crop growth significantly. Some crops have a critical temperature limit as low as 13°C (Ontario Department of Agriculture and Food, 1978). Thus, the use of K- and C-Reactor discharges for soil warming, given an estimated delivery range between 52°C and 75°C, would require a method to lower the temperature before the cooling water could be used for soil warming.

The SCERI (1978) assessment determined that a volume of 21.5 cubic meters per second of water at a temperature of 32.2°C, distributed through a subsurface pipeline, would warm and maintain the soil temperature of a 1000-acre field during early spring. This would allow an approximate 5.6°C reduction in the temperature of the cooling water. Using a combined reactor cooling water effluent volume of 22.6 cubic meters per second at a maximum discharge temperature of 75°C, an estimated additional 50 cubic meters per second of local ambient surface water (at a March ambient Savannah River temperature of 13°C) would be required to provide 32.2°C effluent water for soil warming. Based on SCERI calculations of water distribution, approximately 3395 acres of agricultural land could be warmed using this method. However, the quantity of additional local surface water required to cool the reactor effluent to meet soil warming needs is approximately one sixth of the average annual Savannah River stream flow (295 cubic meters per second) near the SRP.

Reactor operations at the Savannah River Plant would have a significant effect on the supply of heated water available for soil warming. DOE cannot ensure a continuous supply of heated water due to frequent reloading and maintenance activities at the reactors; thus, system users would have to depend on other means for warming the soil when the supply of cooling water from the reactors was not available.

Because soil warming for agricultural purposes is required only during the coldest portions of the year, this method of heat dissipation would not be feasible during the warm seasons. For this reason and because of the need to cool reactor effluents to levels acceptable to plant growth requirements while using only reasonable volumes of local surface waters, the soil warming application would not preclude the need for cooling towers at the SRP.

Based on its assessment of the soil warming application, SCERI (1978) concluded that the potential limited benefits of soil warming do not justify the costs for such a system. Soil warming is useful for, at most, 6 months per year and the use of SRP waste heat is not replacing (and conserving) another energy source because soil warming is not practiced commercially. Estimated costs to the user for installation of the soil warming equipment are \$5000 per acre for what is only an experimental system. The small profit margin for crops that do well on large acreages makes the additional soil warming investment economically unsound for large farms.

In addition to the costs associated with the soil warming equipment and agricultural production, the user would be responsible for all National Pollutant Discharge Elimination System (NPDES) permit requirements for the ultimate disposal of the reactor cooling water effluent after use in the soil warming application.

The estimated costs of the DOE delivery of K- and C-Reactor cooling water to the offsite user location would be the same as those discussed for irrigation. The estimated total construction costs for pumping stations and pipelines for soil warming range between \$188 and \$215 million, and the estimated annual operating costs for these delivery systems would be approximately \$18 million. These costs would be in addition to the DOE costs for construction and operation of the anticipated cooling towers for K- and C-Reactors.

1.3.3 GREENHOUSE HEATING

SCERI (1978) determined that, of the five potential applications it evaluated for the utilization of SRP waste heat, greenhouse heating appeared to be the best prospect. However, as with the other options, SCERI concluded that this application could not be a major use of the waste heat, but it could be incorporated into an industrial/agricultural park as one of the last recipients in an energy cascade. Based on its review of the greenhouse application, ADL (1983) concluded that "some greenhouse operations might be possible and could represent an interesting demonstration activity. However, the presence of low cost heat is not likely to be a sufficient incentive to attract any truly commercial activities."

SCERI (1978) cited a report (Boyd et al., 1977) on an experimental greenhouse facility in Minnesota that used cooling water waste heat from a powerplant of Northern States Power Company for both heating and cooling purposes. This greenhouse has been used for the successful production of tomatoes, lettuce, and roses during the winter.

The Pennsylvania Power and Light Company (PPL) has established a greenhouse complex at its Montour Steam Electric Station (a coal-fired powerplant in east central Pennsylvania) to deliver heat to greenhouse operators (PPL, 1982). PPL uses the discharge from the plant's cooling towers rather than directly from the condensers because the greenhouse operators could not process water warmer than 45°C. Based on a flow rate of 0.022 cubic meter per second of 37.8°C cooling water (annual average) per acre of greenhouse, this system, as presently operating, has the capacity to supply 34 or 17 acres of greenhouses with or without pump assistance, respectively. At the time of the report, 13 greenhouse acres were under cultivation. This application utilizes approximately 1 percent of the plant's cooling water with an approximate 5.6°C reduction (to 32.2°C) in cooling water temperature for return to the plant.

The PPL greenhouses employ an underfloor heating system and an overhead (air heater) system. Each greenhouse operator had to install full-capacity gas- or oil-fired backup heating systems and self-draining pipes to ensure the maintenance of suitable temperatures in the greenhouse during powerplant outages and extremely cold periods.

If the PPL figures are used as a basis for estimating the amount of greenhouse area necessary to lower the temperature of the cooling water discharges from K- and C-Reactors without cooling towers and still meet a discharge temperature of 32.2°C, 30.2 cubic meters per second of local surface water at ambient Savannah River temperature in January (approximately 10°C) for dilution/cooling and 2402 acres (not including associated equipment and access areas) of greenhouses would be required.

PPL estimates that its 34-acre greenhouse cost \$35,650 per acre to construct and that the annual heating cost (annual charge for the pipeline) is about \$13,290 per acre (PPL, 1982). The SCERI (1978) study at SRP estimated the capital costs of greenhouse construction at \$43,560 per acre, with an annual energy cost of \$7675 per greenhouse acre.

Based on an estimate of 2402 acres of greenhouses needed to dissipate the waste heat from K- and C-Reactor discharges without a cooling tower and meet a 32.2°C discharge temperature, greenhouse construction costs (excluding costs for the delivery of cooling water from the reactors) would range between \$86 and \$105 million; annual energy costs would range between \$18 and \$32 million.

When the heat in the water used for greenhouse heating is not dissipated to required levels, discharge of this water would require a cooling system, such as a cooling tower, to meet South Carolina water-quality standards.

I.4 POTENTIAL AQUACULTURAL APPLICATIONS

I.4.1 PRAWN PRODUCTION

The SCERI (1978) report found that, for biological, technical, and economic reasons, the freshwater prawn (Macrobrachium rosenbergii) was the only crustacean with commercial culture potential at the SRP. However, because no commercial prawn farms of the type envisioned exist, the SCERI report concluded that extensive pilot-scale testing and research would be required to determine the extent of this economic potential.

The SCERI study determined that the greatest potential for commercially successful prawn farming in the local area would result from the use of a combination of very intensive indoor and outdoor culture systems. A production plan was proposed for a controlled-environment pilot operation that would utilize indoor tanks for the brood-stock, hatchery, and nursery phases and outdoor ponds for the production phase, during which juvenile prawns would be grown to marketable size. The local climate is such that prawn culture can occur outdoors only during the warmer months of the year. Thus, the cooling water from K- and C-Reactors could contribute heat to an aquaculture operation during the colder months. The low-level waste heat from SRP reactor cooling water could be used to maintain water temperatures in a range favorable to prawn growth (26-30°C), making year-round production possible. However, the presence of tritium in the reactor cooling water precludes direct contact with the prawn culture medium [21 USC 321(s) and 342(a)(7)]; therefore, waste heat could only be used indirectly, through a heat-exchange system, to heat the culture water. This would necessitate the local availability of large volumes of high-quality water (uncontaminated with biocides from agricultural uses,

industrial wastes, etc.) for the culture medium. In addition, the commercial feasibility of using SRP waste heat for prawn production would depend on the cost of the heat-exchange system best suited for large-scale production, which could be determined only through pilot-scale testing.

Water temperatures higher than 33°C are detrimental to prawn growth; accordingly, during the warmer periods of the year, the use of outdoor ponds for heat dissipation would be negligible. (Intensive indoor tank culture would allow year-round use, but would require only relatively small volumes of reactor cooling water for tank warming.) Conversely, a continuous supply of heated cooling water would have to be provided to the prawn farm during the colder months. Any significant interruptions in this flow could result in the complete loss of the prawn crop. Therefore, a backup heating system would be required to ensure controlled maintenance of suitable temperatures during periods of reactor shutdown.

The SCERI report concluded that the potentially most feasible and economically successful system for prawn production using SRP waste heat would be with intensive management techniques using small (1/4-acre) ponds and maintaining high densities of individuals in the ponds. The estimated potential production from such intensively managed units ranges from about 6000 to 8100 kilograms of whole prawns per acre per year. The type of system envisioned by the SCERI studies would use 10 to 100 acres of growout ponds plus associated hatchery and nursery facilities. SCERI assumed that circulation of SRP heated water would be required for 8 months of the year. During the coldest periods, SCERI estimated that a maximum volume of 0.022 cubic meter per second of 38°C reactor cooling water effluent (assuming that pond water could be heated 14° to 17°C via the heat exchangers) would be required for heating each 1/4-acre pond. Considering the maximum prawn farm size suggested by SCERI of 100 acres, pond heating during the coldest portion of the year would be able to utilize only 8.8 cubic meters per second (39 percent) of the total cooling water effluent from K- and C-Reactors. Some other form of cooling of the effluent would be required for the remaining volume (13.8 cubic meters per second) to meet regulatory requirements. Also, SCERI determined that additional cooling of the reactor effluent (to reduce the temperature to 38°C) would be required before passage through the culture system heat exchangers for maintenance of suitable temperatures in the ponds.

The use of cooling water from K- and C-Reactors for prawn production would require the delivery of this water via a pipeline to an offsite prawn producer(s). In addition to the costs associated with the delivery of the cooling water (estimated construction costs of between \$188 and \$215 million and estimated annual operating costs of about \$18 million), cooling systems (once-through or recirculating cooling tower) would still be required to meet environmental standards during the warm season when the prawn producer(s) would not need the cooling water from the reactors.

1.4.2 CATFISH PRODUCTION

The SCERI report (1978) examined raising such noncrustacean food organisms as clams, eels, and exotic fish such as tilapia. Due to the lack of literature on the potential environmental impacts for an inadvertent introduction of

these species into the South Carolina environment, and due to specific technical difficulties with the culture of each species, SCERI eliminated most of these candidates from further consideration as potential aquaculture products. However, it did consider channel catfish (Ictalurus punctatus) culture as a potential application. Catfish farming is presently centered along the Mississippi River, particularly in Louisiana, Mississippi, and Arkansas, where the major portion of the product market also exists. In comparison to the freshwater prawn, the per pound value of catfish is lower and, while prawns are relatively disease-free, catfish are particularly susceptible to certain bacterial, viral, fungal, and algal diseases that often occur under culture conditions. Because these factors would greatly influence the economic feasibility of a commercial catfish operation using reactor waste heat, SCERI determined that the establishment of a research facility would be required to develop the technology of growing catfish in heated ponds and raceways and to develop strains that would be better able to cope with stressful environments and diseases.

Channel catfish have optimum growth and feed conversion at relatively high temperatures (28.9°-31.1°C). Using SRP waste heat, a catfish culture system could expand what would normally be 7 to 8 months of production in the southeastern United States to year-round production. However, the presence of tritium in the reactor cooling water precludes direct contact with the catfish culture medium [21 USC 321(s) and 342(a)(7)]; therefore, waste heat could only be used indirectly, through a heat-exchange system, to heat the culture water. This would necessitate the local availability of large volumes of high-quality water (uncontaminated with biocides from agricultural uses, industrial wastes, etc.) for the culture medium. In addition, the commercial feasibility of the use of SRP waste heat for catfish production would depend on the cost of the heat-exchange system best suited for large-scale production, which could be determined only through pilot-scale testing.

Optimum catfish production requires culture water temperatures of 28.9° to 31.1°C. Water temperatures must remain above 15.6°C if the fish are to continue to grow throughout the year; at temperatures greater than 32.2°C, the fish do not feed regularly. Accordingly, during the warm periods of the year, the use of outdoor ponds for reactor heat dissipation would be negligible. Conversely, a continual supply of heated cooling water would have to be provided to the catfish farm during the colder months; any significant interruptions in this flow could result in complete loss of the catfish crop. Therefore, a backup heating system would be required to ensure maintenance of suitable temperatures during periods of reactor shutdown.

Open ponds are the most common facilities used in catfish production, and their cost in relation to the volume of fish produced is less than that of other facilities such as cages and raceways. Cage culture accounts for only a small proportion of commercial production, used where the culture water is not readily seined (for collection of grown fish). Additional research is required before cage culture could be adopted on a wide scale. Raceways are generally used when only a small amount of land is available for farming. In pond culture, spawning and fry-rearing ponds are usually 1 acre in size, while the most profitable size for growing ponds appears to be 20 acres.

While the SCERI (1978) study did not quantify potential cooling water use or the degree of heat dissipation possible using a heat-exchange system with catfish production ponds, the limitations for waste heat utilization probably would be similar to those for prawn pond farming; that is, (1) that pond heating could utilize only a fraction of the cooling water available from K- and C-Reactors, and (2) that the volume of cooling water that could be utilized for pond heating would require some precooling prior to passage through the heat-exchange system. As with prawn farming, these limitations would necessitate an additional means of reactor effluent cooling to meet regulatory requirements and to make available a usable source of waste heat.

The SCERI study (1978) estimated that it could cost as much as \$20,000 to construct a 20-acre pond. Construction of a 50-acre pond would require an estimated \$60,000. Enclosing the hatcheries and brooding tanks could double the costs. In addition, SCERI estimated that annual operational costs could amount to more than \$1 million for every 640 acres of ponds.

The use of cooling water from K- and C-Reactors for catfish production would require the delivery of the cooling water via a pipeline to an offsite producer(s). In addition to the costs associated with the delivery of this water (estimated construction costs of between \$188 and \$215 million and estimated annual operating costs of about \$18 million), cooling systems (once-through or recirculating cooling tower) would still be needed to meet South Carolina water classification standards during the summer, when the catfish producer(s) would not need the cooling water from K- and C-Reactors.

I.5 ETHANOL PRODUCTION

The technology for ethanol production is fully established; a considerable amount of development and market research has been completed during the past decade. The largest markets for ethanol would be as fuel for engines or as gasoline blending stock (gasohol). The market for gasohol currently exists. At present, however, this market in the United States cannot compete economically with the price of gasoline.

Even though gasohol marketing efforts during the past 10 years have diminished with the decrease of subsidy support from tax credits and the reduction of economic incentives with the fall in crude oil prices, there is still a potential for ethanol to help offset declining U.S. crude oil production. Due to its strong octane-enhancing properties, a barrel of alcohol displaces more than a barrel of crude oil.

Waste heat from K- and C-Reactors at 77°C could be used economically for ethanol production until it reaches 55°C; technically, it is possible to use this heat to a minimum of 32.2°C. The ethanol production process is a batch activity, during which cooling water must be supplied continuously. Because the production process could not always accept the waste heat, the ethanol facility would require a cooling water system to meet the South Carolina water-quality standards.

The Office of Technology Assessment (OTA) prepared a study to evaluate ethanol production potential (OTA, 1980). A slurry of biomass material (grains are

preferred but other crops can be used) would be prepared at ambient temperature; it would be heated to about 90°C to promote enzyme development. The high-temperature enzyme addition accelerates the fermentation process. After fermentation, a mechanical separator would remove the solids, fibers, and particles from the slurry. Depending on the biomass source, the removed solids could be dried, caked, and used as animal feed. This drying operation would start at about 90°C and require a temperature higher than 100°C to be efficient; therefore it would not be a potential application for the waste heat from K- and C-Reactors because the cooling water temperatures are too low.

The use of the available waste heat for the major energy requirement (i.e., the distillation and purification operation) for this process would require a departure from the normal commercial practice - performance of the distillation at a partial vacuum pressure. This would lower the reboiler temperature requirement, but it would add significantly to the required capital costs. Of even greater concern, this departure would remove the process from a well-established commercial practice.

The OTA report (1980) concludes that a 38 to 189-million-liter-per-year process plant was the largest that should be built, due to the requirements for transporting the biomass material to the facility and for transporting the ethanol to market and the byproduct (the dried stillage) to a disposal point or a secondary market. The OTA report states that an acre of corn could produce 640 to 980 liters of ethanol per year in such a process. This report estimates that the ethanol production costs for a 189-million-liter-per-year plant would be about \$0.32 per liter and that product delivery costs would be about \$0.08 per liter, for a total product cost of \$0.40 per liter. OTA further concluded that ethanol as an octane-boosting additive to gasoline would not be economical until crude oil prices ranged from \$20 to \$30 per barrel (in 1980 dollars). If the SRP waste heat were provided free to the producer, the savings realized would only be about \$0.02 per liter, which would not be of great importance in a decision to build such a plant.

A variety of biomass feedstocks could be used in the process. The OTA (1980) and Rogers (1980) studies indicate that the best crops are corn or grain sorghums. Both of these grains produce a solid byproduct that is suitable for processing as an animal feed. Because the Savannah River Plant is not located in a major corn or grain growing area, crop transportation costs would be significant. Also, as indicated above, existing ethanol production facilities are operating at well below full capacity due to depressed crude oil prices.

Clemson University (Cross et al., 1982) studied the feasibility of using waste heat from SRP reactors and root crops such as sweet potatoes and Jerusalem artichokes as feedstock. The estimated production costs of ethanol using these crops ranged from \$0.42 to \$0.45 per liter, excluding the cost of the feedstock. This study indicated that further study along these lines would not be productive unless a significant cost-reduction breakthrough in harvesting or processing technology is achieved.

I.6 SUMMARY

None of the potential applications for the utilization of SRP waste heat are considered substitutes for cooling water systems because of institutional,

technical, and economic problems. Rather, such costs are considered additive to the construction and operation of cooling water systems for K- and C-Reactors. Reactor cooling water cannot be used directly on crops or other food products because of the presence of tritium in the cooling water discharges. This precludes direct contact use for irrigation of crops and as an aquacultural growth medium. Reactor effluent could be used indirectly in agriculture or aquaculture through the warming of crop soils or the heating of greenhouses or prawn or catfish culture ponds, requiring the use of expensive heat-exchange systems. Such agricultural and aquacultural applications are of seasonal value, required only during the coldest months of the year. Even during the period of use, these applications alone would not dissipate sufficient waste heat to meet State temperature discharge requirements. These potential applications, as well as an ethanol production facility, would require significantly greater capital costs (Table I-2) than recirculating or once-through cooling towers and would take several years to implement, even if commercial operators could be identified. For these reasons, the Department of Energy does not consider the agricultural, aquacultural, and ethanol production applications to be reasonable alternatives to the construction and operation of once-through or recirculating cooling towers for K- and C-Reactors.

Table I-2. Costs for Alternative Cooling Systems and Waste Heat Applications for K- and C-Reactors

Alternative/application	Capital cost (\$ million)	Annual operating cost (\$ million)
Once-through cooling towers	\$87	\$0.4
Recirculating cooling towers	\$190	\$2.4
Irrigation ^a	\$275-302	\$18.4
Soil warming ^a	\$275-302	\$18.4
Greenhouses ^b	\$86-105	\$18-32
Aquaculture ^a	\$280-324	\$4-6
Ethanol production	\$NP ^c	\$NP

- a. Estimated costs include the costs for once-through cooling towers (because cooling water discharge temperatures are too high to be used during summer) and the costs for delivery of cooling water to the SRP boundary; they do not include costs of user irrigation, soil warming, or production systems (ponds).
- b. Estimated costs do not include the costs of delivery of cooling water discharges or of the cooling system that might be required for discharge of the warm water from the greenhouse.
- c. NP = Technology not practicable unless gasoline prices rise significantly or there is a cost reduction breakthrough in harvesting feedstock or processing technology. (Note: The estimated capital cost of an ethanol production facility would exceed several hundred million dollars).

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APPENDIX J

COMMENTS AND DOE RESPONSES ON DRAFT ENVIRONMENTAL IMPACT STATEMENT ALTERNATIVE COOLING WATER SYSTEMS

During the public comment period from March 28 through May 19, 1986, the U.S. Department of Energy (DOE) received 27 statements and/or comment letters on the draft version of this environmental impact statement (EIS). In addition, three comment letters were received after May 19, 1986. The 30 statements and letters included eight from Federal agencies, seven from agencies and offices of the States of Georgia and South Carolina, five from individuals associated with various colleges and universities, two from members of the United States House of Representatives, and eight from concerned individuals.

This appendix presents the individual statements and/or comment letters and DOE's responses to them. If a comment has led to a text revision in this EIS, the revision is identified with a vertical line in the margin, a comment letter, and a number designation. Table J-1 lists the comments received, and Table J-2 lists the individual comments and DOE responses.

Comments received at the public hearings and during the subsequent comment period dealt with the following issues:

- Alternative uses of cooling water for various agricultural, aquacultural, and power production purposes
- Cost breakdown, present worth analysis, projected lifetime, and thermal performance for cooling towers
- Establishment of an independent review group for all environmental impact statements
- Preference for recirculating cooling towers due to cost and environmental soundness
- Impact of chlorination and corrosion inhibitory compounds upon the aquatic environment
- Incorporation of predictive Section 316(a) type information
- Analysis of entrainment of fish eggs and larvae

DOE has responded to all these issues and has included additional information in some chapters and appendixes as appropriate.

Table J-1. Comments and Statements Received on the
Alternative Cooling Water Systems
Environmental Impact Statement

Designation	Individual or organization	Page
AA*	Henry D. McMaster	J-3
AB*	Heinz J. Mueller	J-6
AC*	Harry Busbee	J-7
AD*	William N. Wheeler	J-8
AE*	Bart Ruiter	J-10
AF*	Richard Hegg	J-11
AG*	Roger Dale Wensil	J-13
AH*	Richard Dickison	J-16
AI*	Frank Watters	J-18
AJ*	Diane Mahoney	J-19
AK*	Sam Schillaci	J-20
AL*	William F. Lawless	J-23
AM	Ralph F. Cullinan	J-29
AN	Sherman R. Ellis	J-30
AO	William D. Anderson, Jr.	J-31
AP	Bruce Rippeteau	J-33
AQ	J. Leonard Ledbetter	J-35
AR	Richard W. Riley	J-37
AS	Richard O. Hegg	J-39
AT	Charles E. Lee	J-42
AU	Danny L. Cromer	J-45
AV	Hilary J. Rauch	J-48
AW	Thomas F. Hartnett	J-49
AX	Butler Derrick	J-51
AY	John C. Villforth	J-54
AZ	Don L. Klima	J-56
BA	Dan M. Mauldin	J-58
BB	James A. Joy, III	J-60
BC	Jack E. Ravan	J-66
BD	Bruce Blanchard	J-91

*Comments or statements received at public hearing held by DOE on the Draft EIS on April 30, 1986.

Table J-2. DOE responses to comments on Draft EIS

Comment number	Comments	Responses
	TESTIMONY OF HENRY D. McMASTER, APRIL 30, 1986, BEFORE THE ALTERNATIVE COOLING WATER DRAFT EIS PUBLIC HEARING	
	Thank you, ma'am. I'm very happy to have the opportunity to speak to you today on this issue, and appreciate your taking the time to conduct this hearing. I know the people of this area and of the state are very interested in the Savannah River Plant because it is a very important part of our state.	
AA-1	There are just a few things that I'd like to say, and basically, this deals with the one alternative to the cooling towers, or any other form of cooling the water, and that is the irrigation system. It is a system which has been recommended for study by Clemson University and the Department of Agriculture, and I think as a private citizen, and also one interested in public affairs, I think that this is something that needs to be included in the Environmental Impact Statement, because I believe we must study the issue, here, to see if there aren't ways to put more back into the state; to have some more positive benefits flowing to the state than are presently flowing from the Savannah River Plant, and of course, those benefits now are substantial to the state and to the nation. But, we have a good opportunity, here, I believe, to do something positive for the state, for the State's economy, particularly in terms of the farm industry, the farm, the farmers. So those, briefly, that's what I had in mind. I'll say this: I think that instead of treating the huge amount of heated water and potential energy it represents - which is estimated to having a value of about a half a billion dollars a year - as a nuisance, and something we should worry about being	DOE has incorporated a new appendix in this EIS (Appendix I) that addresses the feasibility of using the cooling water discharges from K- and C-Reactors for agricultural and aquacultural uses, industrial applications, direct power generation, and ethanol production.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	disposed of, we should be studying the alternatives for harnessing this for future economic development of this area and the State of South Carolina, because it does provide some tremendous opportunities for us. There are many needs for heated water in various industries. Besides attracting new industries, this heated water could benefit the area farmers if used for inexpensive irrigation or crop drying. The nation's fuel consumers could benefit from the inexpensive production of ethanol this heat could produce, not to mention the area farmers who could produce the raw materials from various row crops, including turnips, rutabagas, parsnips and all sorts of other things, that Clemson University has been talking about. In my opinion, I think what we should do is work to redefine the role of the Savannah River Plant. We would all benefit if the bureaucratic red tape that's in all government, especially the Federal Government it seems, were cut and if the blinders which narrow us to the potential benefits of this plant were taken off. I think that we cannot allow the opportunity that this resource--this hot water--presents to the people of this region, for economic growth, to be thrown away by the construction of very expensive water-cooling towers. Instead, we must look toward ways of using this energy to benefit all of the area's people; and the Savannah River Plant's role should be redefined in that fashion, I believe, so that it can make these additional major contributions to the economy and ecology of South Carolina. But, in a nutshell, this is what could happen: instead of taking this hot water and cooling it for later discharge into the river, we could have all sorts of things to be based upon that. I understand that the water from the present reactors is not hot enough to produce electricity. If a new production	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	reactor were built here--and I understand there's question about that--of course, that water would be hot enough; it could be used in that fashion to produce electricity and could possibly reduce heating bills about \$200.00 per family around South Carolina, I am told. But, with the present reactors that we have, the hot water could be used, number one, to create ethanol which, of course, doesn't have the environmental problems associated with it of coal, and the regular gas-burning automobiles. And, also, that after the crops that are used, like parsnips, rutabagas and turnips that have a much higher starch and protein and sugar content than other crops that are used to make those--to make the ethanol--the residue could be used to feed hogs, for example, could be used for feed all around the state. So, you could have a whole industry developing of farmers growing these row crops that they can't grow, now, because it's too expensive to dry them, and they're about ninety percent water, and it's just too expensive to dry them in order to ship them around the country. So, people don't get into that. If we were to use the heat given off by the present system in that fashion, we could build up that farming industry, that part of the farming industry; create new industries for feeding hogs, things of that nature; and then, take the water and run it through, for instance, part of Allendale County. I'm told there are about 300,000 acres that could be irrigated there by the water, and it would be very helpful. As far as the new production reactor goes, which is not a question, here, I believe that if it is constructed, here, when it is constructed, here, it should also be viewed from these same viewpoints, to see if these types of positive benefits could be built into that system to benefit the people of this area.	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
TESTIMONY OF HEINZ J. MUELLER, APRIL 30, 1986, BEFORE THE ALTERNATIVE COOLING WATER DRAFT EIS PUBLIC HEARING		
AB-1	I'm Heinz Mueller. I'm with US EPA in Atlanta. EPA is currently reviewing the draft Environmental Impact Statements to determine which of the alternatives provide the least impact to the environment. We will be submitting formal comments to DOE by mid-May, and we're primarily here today to listen to any comments and concerns. We appreciate the opportunity to participate. And that's really all we have to say today. Thank you.	Comments noted.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
AC-1	TESTIMONY OF HARRY BUSBEE, APRIL 30, 1986, BEFORE THE ALTERNATIVE COOLING WATER DRAFT EIS PUBLIC HEARING	
	I am Harry Busbee, and I am Assistant to the Commissioner of Agriculture for the State of South Carolina. I am representing Commissioner of Agriculture, Leslie Tindall, here today. I think you all realize the plight of the South Carolina farmer today, and when we are twelve or fifteen inches less water this year than we were last year, I think that we realize in agriculture how important the waste water at the Savannah River Plant can be to agriculture. We at the South Carolina Department of Agriculture would like to recommend to the Department of Energy and to the Savannah River Plant to consider including in the Environmental Impact Statement the use of irrigation and/or aquacultural use of water as a means of heat abatement. I realize that this is a very complex issue and one not easily resolved. Your consideration in including irrigation and/or aquacultural use of water as a means of heat abatement in the EIS would be greatly appreciated. Thank you.	DOE prepared a new appendix in this EIS (Appendix I) to address the feasibility of using the cooling water discharges from K- and C-Reactors for agricultural and aquacultural uses, industrial applications, direct power generation, and ethanol production.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	TESTIMONY OF WILLIAM N. WHEELER, APRIL 30, 1986, BEFORE THE ALTERNATIVE COOLING WATER DRAFT EIS PUBLIC HEARING My name is William N. Wheeler. I am here on my own behalf and I have a statement to make in an effort to get an answer to a question.	
AD-1	Any of the DOE information that I have seen in the past following through with the late investigation in L-Reactor gave cost figures, but they gave no breakdown of those costs; and having been employed as an engineer in the fuel and power industry, I would be very curious as to see the cost breakdown of the estimates as far as the money being expended. It is an extremely large sum of money; and I think the public should be shown how the money should be spent. Thank you.	The cost breakdown for cooling towers varies with the type of tower and the location selected. The following breakdown of costs for cooling tower systems under consideration was developed for planning purposes. These percentages would range between the values presented when the final design has been approved. <u>Mechanical draft, once-through or recirculating towers</u> 1. Cooling tower, tower basin, tower foundations, tower preparation area, (leveling, grading) diversion boxes, pump pits and piping, 79 to 83 percent of the estimated cost. 2. Electrical distribution upgrade, extension of power to tower site, and electrical control building at the tower site, 12 to 17 percent of the estimated cost. 3. Canals, headwalls, clearing and grubbing, access roads, chlorinated and dechlorination systems, including chemical storage, 3 to 6 percent of the estimated cost.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
		<u>Gravity-fed, once-through or recirculating towers</u>
		1. Cooling tower, tower basin, tower foundations, tower preparation area, (leveling, grading) diversion boxes, pump pits and piping, 71 to 83 percent of the estimated cost. 2. Electrical distribution upgrade, extension of power to tower site, and electrical control building at the tower site, 7 to 19 percent of the estimated cost. 3. Canals, headwalls, clearing and grubbing, access roads, chlorination and dechlorination systems, including chemical storage, 10 to 13 percent of the estimated cost.
		Also see response to comment BC-6.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
TESTIMONY OF BART RUITER, APRIL 30, 1986, BEFORE THE ALTERNATIVE COOLING WATER DRAFT EIS PUBLIC HEARING		
AE-1	I'd just like to say, my name is Bart Ruitter. I'm with the South Carolina Department of Health and Environmental Control. We also are currently reviewing the draft EIS and we should have our comments in by May 19th. That would be it.	Comments noted.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	TESTIMONY OF RICHARD HEGG, APRIL 30, 1986, BEFORE THE ALTERNATIVE COOLING WATER DRAFT EIS PUBLIC HEARING PUBLIC HEARING ON HEAT ABATEMENT PLANS FOR THE SRP April 30, 1986 Aiken, SC Richard Hegg, Head, Agricultural Engineering Dept Clemson University, Clemson, SC	
AF-1	I am aware of the proposed plan to construct a heat abatement facility at the Savannah River Plant. The purpose of this statement is to request that one option for this heat abatement should be irrigation on cropland, pastureland, and forest in the area of the Savannah River Plant. I feel this is a technically feasible option; therefore, it should be addressed by DOE and the Savannah River Plant. It is logical to utilize this resource, being a large volume of heated water, rather than building cooling lakes or cooling towers. The option of irrigation would be of benefit to South Carolina agriculture, and would show that the Savannah River Plant is interested in a project that would emphasize utilization of a resource. There are many points that would need to be addressed, such as legal, crops, climatic effects, surface water, ground water, wildlife, off-season use, social, economics, and the overall organization. It would be appropriate that a feasibility study be conducted, and I would be happy to work with those persons preparing an environmental statement, to work on this study of a large-scale irrigation project. There are scientists at Clemson University and professionals with state agencies within the state to adequately provide the necessary technical assistance.	DOE prepared a new appendix in this EIS (Appendix I) to address the feasibility of using the cooling water discharges from K- and C-Reactors for agricultural and aquacultural uses, industrial applications, direct power generation, and ethanol production.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
		And to elaborate a little bit, I've talked with several people at Clemson regarding this, and contacts with other agricultural interests in the state, and I believe this morning a representative of Les Tindall's office, the Commissioner of Agriculture, was here also expressing support of this idea. We feel that, as I pointed out, there may be many potential problems, but it certainly would be something that needs to be addressed. And, I am not aware that this option has been addressed or there will be a response to this question, but I would certainly like to know that. And, I feel that with the volume or the amount of money that would be invested in these cooling towers, that certainly a feasibility study prior to the initiation of that would be beneficial, and if it came out that it would not be practical, would not be feasible, that it would stand on that basis. But it certainly, we feel, would need to be addressed. And I would encourage you to proceed on this, and I guess I would be waiting for a response from the representatives here, if I could be of help or make contacts as would need to be made. So, at that point, that concludes the comments I'd like to make. Thank you for the opportunity.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
STATEMENT OF ROGER DALE WENSIL Roger Dale Wensil 14 Creek Court Aiken, SC 29801		
AG-1	My statement deals with the construction of this proposed cooling tower project as well as other construction, maintenance and operations activities on the Savannah River Plant.	These comments are outside the scope of this EIS.
	I would like to address this meeting about the problem of illegal drug use on the Savannah River Plant.	
	We all know the nature of the work on the Savannah River Plant, and because of the potential dangers involved in this work, I say that if there is any place in the United States that should be drug-free, the Savannah River Plant is it.	
	Drug users pose a terrible danger to us, whether they work in construction, operations, or maintenance.	
	You are being too lenient on these drug users. Your policy of rehabilitation for drug users is admirable, but I feel that for our protection, these people should be permanently removed from the Savannah River Plant.	
	At present, people who are found to have drugs in their bodies on the Savannah River Plant are sent home for thirty days, and then are allowed to return to work.	
	One of your chief responsibilities is the safe operation of this facility. By knowingly allowing known drug users to return to work on the plant	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	site, you are just as guilty as they are in the event of an accident. In such an event, I feel that the courts of this land would find you, the Department of Energy, criminally negligent and liable for any damages done to us by these drug users. The South Carolina Electric and Gas Company and the Georgia Power Company have a policy that when a person is found to have drugs in their system while at work, they are fired and permanently barred from employment. I believe the citizens of Aiken County deserve at least the same protection as the citizens being protected by these companies. I say that for the protection of the people of this area that no construction, operation or maintenance work should be done on the Savannah River Plant until this dangerous situation is corrected. These drug users have the potential to cause the most disastrous effect that can be imagined on the environment. Fire these drug users and bar them from future employment. Replace them with people who realize the responsibilities that go along with a job on the Savannah River Plant. There are plenty of qualified people looking for jobs who would be glad to have the jobs that these drug users seem to have so little regard for. I have deliberately not quoted the figures available to me concerning drug use on the plant site, but I think that if the people of this area were aware of what a serious problem you allow to exist on the site, it would scare the hell out of them.	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	I challenge DOE to report to the public on a regular basis the percentage of people, plant wide, who test positive in your drug abuse program, and what actions you take. Thank you.	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
TESTIMONY OF RICHARD DICKISON, APRIL 30, 1986, BEFORE THE ALTERNATIVE COOLING WATER DRAFT EIS PUBLIC HEARING Draft Environmental Impact Statement Aiken, South Carolina April 30, 1986 Comments of Richard Dickison		
AH-1	Hot water from the Savannah River Plant should not be considered a waste product, but a useful by-product. Presently, the Sandoz Company in Allendale County is burning fuel oil to make hot water. The hot water from Savannah River Plant could be purchased by Sandoz or other companies to make American products more competitive. Allendale currently has a depressed economy. Low-cost industrial hot water could be the economic incentive needed to attract new industries to Allendale County and Barnwell County. Instead of spending in excess of a hundred million dollars to create a capital structure which turns an economically feasible raw material or source of low-grade heat into plain river water, the Department of Energy should explore the possibilities of piping the hot water to Allendale County for use in existing or new industries. It may well be feasible to construct an insulated pipe and associated pumping facilities under the cost of constructing cooling towers, and, by marketing the hot water to industries, establish a reasonable pay-back period. Eventually, the sales of hot water could become a profit center for the Department of Energy. Certainly, the discussed plans using the hot water to produce ethanol and the spent water to irrigate	DOE prepared a new appendix in this EIS (Appendix I) to address the feasibility of using the cooling water discharges from K- and C-Reactors for agricultural and aquacultural uses, industrial applications, direct power generation, and ethanol production.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	root crops used as the feed stock (sic) for the ethanol plant need to be fully explored before any construction of cooling towers begins. America needs jobs and Allendale and Barnwell Counties could certainly use the economic benefits created by new industry developed from farming and ethanol plants. Thank you. ADDITIONAL COMMENT: I have regretted that the ethanol plant has not so far been discussed in detail, and I suggest that a discussion of such a plant be included with the statements being prepared. Thank you.	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
TESTIMONY OF FRANK WATTERS, APRIL 30, 1986, BEFORE THE ALTERNATIVE COOLING WATER DRAFT EIS PUBLIC HEARING		
AI-1	I put my name down there to make sure that the subject that has already been discussed was going to be on the agenda and into the minutes, which was the utilization of the energy source from the hot water. Both the gentlemen, Mr. Hegg, and the previous gentleman, here, recommended that the DOE study the use of the water as irrigation and also as a heat source for the proposed demonstration ethanol plant. I think it's feasible. I'm quite familiar with quite a bit of what goes on at Savannah, having had thirty-one years' experience in it, and have studied the use of heat, for example, from spent fuel for irrigation or heating and other things. I know there are some problems, but I think those can be overcome by the double-containment system, which everybody should be familiar with. So, my only purpose was, getting my name on there, was not to be heard, but to make sure that the topics I was going to cover were covered, and they have been covered and I would second those recommendations. Thank you.	DOE prepared a new appendix in this EIS (Appendix I) to address the feasibility of using the cooling water discharges from K- and C-Reactors for agricultural and aquacultural uses, industrial applications, direct power generation, and ethanol production.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	TESTIMONY OF DIANE MAHONEY, APRIL 30, 1986, BEFORE THE ALTERNATIVE COOLING WATER DRAFT EIS PUBLIC HEARING	
AJ-1	I have just one single question that I hope someone here can answer. Where does P-Reactor fall in all of this, and why has it been excluded in your consideration of cooling water alternatives? Specifically, can you tell me where ponds 1 through 4, and pond C fall in all of this? Is there someone who is supposed to answer my question, or ?	As stated on page 1-1 of Chapter 1 of the DEIS, discussions of P-Reactor are not within the scope of this EIS. This is because continued use of the recirculating cooling system for P-Reactor was approved by SCDHEC on May 14, 1987, based on Section 316(a) and 316(b) studies conducted by DOE which demonstrated the existence of a balanced biological community in Par Pond.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
TESTIMONY OF SAM SCHILLACI APRIL 30, 1986, BEFORE THE ALTERNATIVE COOLING WATER DRAFT EIS PUBLIC HEARING		
AK-1	I was just going to state about the same thing I stated last time, which you can read in the documents that went out. But, just to kind of briefly go over it, I'm a former employee with Savannah River Plant, and I was retired because of mental problems, and I question everybody here for listening to me, because I'm insane. But, that's beside the point. I did get a pension from the government, so I can't complain. O.K. My stress was brought on because of all the stress that the government, any government employee, can tell you about. Well, anyway, I had six months off without pay, and had time to think a lot, write, which I enjoy, and also I went into business for myself, which has been a plus for me. But, I'd like to correct the grammar here, on the statement, It says, "I like to drink a lot," but that's wrong, "I like to think a lot." I do drink a little bit, not much, but, really, I can't complain. And see, the reason, because my insanity is because I talk to the powers that be. And this accident that happened recently, we really shouldn't worry, because mankind usually works itself out for the best. And all she's wondering about is she would like to have a pony someday. (sic) Way in the future, plus some land to ride it on. But, anyway, that's the insane part. The only thing different I wanted to add today, if I could, is read one of my short stories if that's possible. And I wrote it--I'd like to be a cartoonist someday, but I doubt if I am--I'll just show you, this is an album cover that--I'll show it to the back of the room, here---it's a couple of men. And	Comments noted.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	they look like they're men from Earth, and that's the name of the album cover, but we've got a problem with the world today. There's a lot of men in the world, plus women. But, this is my short story about these two people that I made up. 10/85-F THE KINGDOM OF SOD or A COUPLE OF SONS OF MEN FROM THE GEORGIA BACKWOODS "Hell, Luke, whereabouts we be delivering all this god-durn hay?" I hate to be so dramatic, but I.... "Some durn fool wants it for the land and the stinking horses." "Luke, here I am suffering and dying while this here vomit feeds horses with our blood!" "I know, I'm sick and tired of it. Horses are for working, anybody can tell you that. Not for tickling somebody's underpanties. Even Will Rogers knew that an airplane would take him to heaven. There's just too many snakes in the heads nowadays. Hell, we're all just living on a dream and a prayer. Just like this god-durn government and this kingdom of sod or whatever it is these sons of gad preachers are talking about." "Well, hell Luke, let's say we burn this god-durned hay, and then we get rid of that durned fool and take the land. Then, we could live in that durned farm house like we was virgins." Marco--that's the other guy's name, I named him Marco.	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	"I'm hungry for action. I'm sick and tired of this nowadays love. Let's get a moving."	
	I speak crazy a lot, but to me it makes sense. But, anyway, I'd like to just stress to the government that they should really take their time with all their plans, and sometimes they think too much, and maybe a sabbatical will help some people. Who knows. It's up to the individual. I know it's not all for some people, they're in it for the money. But, for other people like myself, I'm here for a good time. So, to end my story, here, I'll repeat my demands, but I've reduced them a little bit. I'll take a quarter of a million dollars, a reporter named Lois, and an Indian princess probably named Lily, and I don't care about going to New Zealand, because they've probably got reactors down there anyway, and I'll shut my mouth. But I think the plant won, because my father came to move me back to Birmingham. Thank you. I have been a thorn in the side of the plant, and they can attest to that, too.	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	TESTIMONY OF WILLIAM F. LAWLESS APRIL 30, 1986, BEFORE THE ALTERNATIVE COOLING WATER DRAFT EIS PUBLIC HEARING	
	Review Comments: Alternative Cooling Water Systems DEIS (DOE/EIS-0121D)	
	W. F. Lawless Assistant Professor of Mathematics Paine College April 30, 1986	
	Review Comments: Alternative Cooling Water Systems DEIS (DOE/EIS-0121D)	
	The recommendation of cooling towers in the Alternative Cooling Water Environmental Impact Statement represents a positive step forward. The Cooling Water EIS recommends a cooling water tower alternative instead of the cooling lake that was chosen for the L-Reactor. Nonetheless, this EIS is a highly technical document, but it has been written by experts for the purpose of informing a technically unsophisticated public about a subject few have the time, energy or inclination to validate.	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
AL-1	EIS statements are a step forward in their own right, because researchers with the inclination can delve into these studies. Yet, few researchers will review an EIS. Even fewer have the training to understand the doubly technical meanings, and still fewer have the experience to know what to look for unless they already work for the DOE. For example, during a recent talk in Las Vegas, I made a reference to the contaminated basins on the nearby Nevada Test Site. One person in the audience, a DOE contractor employee, denied that contaminated ponds were in use at the Nevada Test Site. However, a copy of the recent Nevada Test Site monitoring report, which discussed contaminated ponds at the site, resolved the issue. Whereas the experience and training were available to offer insight into that situation, that is not always the case, and this EIS is a different matter. No local independent group of qualified technical individuals in the Central Savannah River Area is paid to devote full time to a peer review of this EIS and to provide insight into what this EIS will mean to the citizens of this area.	This EIS has received extensive independent review by several agencies and groups with specialized expertise in evaluating the data and impact assessments provided in the EIS. In developing the EIS, DOE utilized most of the reference material contained in the L-Reactor EIS, used standard methodologies and relied on scientific and other sources of data compiled from more than 200 publicly available documents that had been developed over the past 30 years, including data from ongoing studies. Selection of the alternatives discussed in the EIS was based on the <u>Thermal Mitigation Study</u> that was submitted to the State of South Carolina as required by Consent Order and was subsequently approved. The environmental data utilized in the EIS to assess impacts was primarily derived from the DOE <u>Comprehensive Cooling Water Study</u> which was required by Consent Order with the State of

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
		South Carolina. As discussed in Chapter 5 of the EIS, the State of South Carolina, the State of Georgia, the U.S. Environmental Protection Agency (Region IV), the U.S. Fish and Wildlife Service (Region IV), and the U.S. Army Corps of Engineers participated in this study in a review and advisory capacity. In addition, reviewing agencies provided comments on the scope of the EIS at a public hearing and on the draft EIS at a public hearing and during the 45 day public comment period. DOE provided working drafts of the EIS to the State of South Carolina and the U.S. Environmental Protection Agency (Region IV), met with their representatives, and incorporated their comments into the EIS. All required consultations with agencies on endangered species, historic preservation, habitat evaluation procedures, and permit requirements were completed and discussed in the EIS.
AL-2	A lack of oversight can lead to abuses in the continued use of obsolete practices and equipment. The abuses and antiquated practices used by the engineers and scientists at the Savannah River Plant in the past have been well documented. As examples: the coverup of corrosion-pitting in the high-level waste tanks; coverup of the strontium-90 contamination in turtles at an Savannah River Plant seepage basin and found off the plant in a commercial hog farm; the use of cardboard boxes to dispose of radioactive wastes; the contamination of the Tuscaloosa aquifer and drinking water at the plant for at least two years without informing Savannah River Plant employees and so forth. These	A discussion of high-level waste, Savannah River Plant waste management practices, and containment of radionuclides is outside the scope of this EIS.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	abuses stopped only when the public began to find out about these practices performed by Department of Energy - Savannah River Plant engineers and scientists. But, many other abuses continue: for example, seepage basins, the lack of containment domes on the Savannah River Plant reactors; and the injection of solvents into the air at the Savannah River Plant.	
AL-3	When scientists and engineers operate in a bureaucracy behind closed doors without public oversight or input such as has happened at the Savannah River Plant, abuse is inevitable. When the public gains insight, the exposed abuses stop or are slowed. The Cooling Water Environmental Impact Statement is a difficult document to review within the allotted time. A competent technical review of this EIS should take three to six months, with qualified individuals that have the right to ask the Department of Energy questions and the right to have those questions answered. That last point is very important. Three weeks ago, on April 10, 1986, I was invited to Congress to discuss the new DOE rule on by-product management. The by-product rule redefines most radioactive waste as by-product exempt from EPA and state hazardous waste regulations. The by-product discussion was planned to include introductory statements from both the DOE and a second panel of which I was a member. The introductory statements were to be followed by questions from Congressional members of the subcommittee to both panels in order to debate the by-product rule before Congress. Although DOE made their initial presentation, DOE refused to honor its commitment to participate in an open discussion between the two panels. Three times during the hearing, Congress requested that DOE stay for the peer panel discussion, but to no avail. The Department of Energy walked out.	See response to comment A0-1.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	Secretary Herrington of the Department of Energy claims that the DOE environmental programs are aggressive and that DOE is doing a good job of protecting the environment. Admiral Foley, Assistant DOE Secretary for Defense Programs, stated at that April 10th Congressional hearing, that the public will be the ultimate judge of the waste management job done by DOE. He said this just before he and Mary Walker, who is DOE Assistant Secretary for Environment, Safety and Health, walked out of the meeting. If the DOE programs are aggressive as claimed by Secretary Herrington, the DOE should not be afraid to defend its work before the public.	
	What is needed to properly review this cooling water environmental impact statement is a local independent peer review group composed of technical and non-technical members from the CSRA community affected by this and other EIS statements yet to be presented to the public. This peer review group should be funded by DOE through the State of South Carolina but remain independent of both. Precedents have been set in New Mexico at the WIPP facility and Oak Ridge. Both are as a result of lawsuits filed by the states. The peer review group would have the right to access any technical information or have their technical questions answered. EIS documents would be reviewed by the independent review group, and not presented to the public until their review was completed.	
	For too long, scientists and engineers at the Savannah River Plant have held the upper hand over information released to the public. This practice has led to abuses by an unchecked bureaucracy. Congress has drafted legislation that may lead to the end of this self-regulation by the DOE.	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	Whenever scientists and engineers do not include the public in their decision making process, as in the self-regulation practiced by DOE, the public is held hostage to their work. Not only should such practices cease because the public is excluded, but because such practices are wasteful, and lead to wrong decisions--decisions that are too often destructive to the environment, the public, and the Savannah River Plant employees.	An independent peer review group would provide an important check and balance to the work done at the Savannah River Plant. A local peer review group would establish a partnership between DOE and the public, and it would help improve the Department's credibility. When DOE describes its environmental programs as aggressive, that is just a play on words. However, establishing an independent peer review group would give DOE a chance to put those words into action. In closing, I would hope that the day for self-regulated bureaucracies is almost over. Thank you.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
STATEMENT OF RALPH F. CULLINAN		
<u>STATEMENT ON COOLING TOWERS - RALPH F. CULLINAN.</u>		
<u>AIKEN, S.C.</u>		
AM-1	In my opinion, the outflow of Savannah River Plant reactor cooling water at elevated temperatures causes no damage while using the present set-up. Building cooling towers to remove this heat would represent a total waste of scarce taxpayer funds.	The No Action consideration in this EIS is required pursuant to regulations of the Council on Environmental Quality for implementing the procedural provisions of the National Environmental Policy Act (40 CFR 1500-1508). Chapters 2 and 4 of the EIS present and discuss both adverse and beneficial impacts of the cooling water alternatives considered.
AM-2	If the energy in this cooling water could be harnessed by an agricultural or other process, it would produce a benefit rather than a depletion of economic resources.	DOE prepared a new appendix in this EIS (Appendix I) to address the feasibility of using the cooling water discharges from K- and C-Reactors for agricultural and aquacultural uses, industrial applications, direct power generation, and ethanol production.
	Ralph F. Cullinan 423 Homestead Lane Aiken, S.C. 29801	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
STATEMENT OF SHERMAN R. ELLIS		
United States Department of the Interior Geological Survey U.S. Geological Survey, WRD 1835 Assembly St., Suite 658 Columbia, S.C. 29201 Mr. R. P. Whitfield Director, Environmental Division U.S. Department of Energy Savannah River Operations Office P.O. Box A Akin, South Carolina 29802 Dear Sir:		
AN-1	The Department of Energy Draft Environmental Impact Statement, "Alternative Cooling Water Systems, Savannah River Plant, Aiken, South Carolina" (DOE/EIS-0121D) was reviewed by this office. We reviewed the water quality and hydrology sections of the chapters on Affected Environment and Environmental Consequences. The staff of this office has no technical questions on the water quality and hydrology sections.	Comments noted.
Sincerely, Sherman R. Ellis Hydrologist /kd		

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
STATEMENT OF WILLIAM D. ANDERSON, JR.		
	Telephone Area 803 795-3716	
	College of Charleston Grice Marine Biological Laboratory 205 Fort Johnson Charleston, South Carolina 29412	
	29 April 1986	
	Mr. R. P. Whitfield, Director Environmental Division U.S. Department of Energy Savannah River Operations Office P. O. Box A Aiken, South Carolina 29802	
	RE: DEIS for Cooling Water Systems	
	Dear Mr. Whitfield:	
	I have examined the Draft Environmental Impact Statement (DEIS) (DOE/EIS-0121D) entitled Alternative Cooling Water Systems, Savannah River Plant, Aiken, South Carolina, dated March 1986, and offer the following for your consideration.	
A0-1	Based on the data presented in the DEIS the construction of recirculating cooling towers for C- and K- Reactors is by far the best alternative in each case because it would result in a considerable improvement in water quality and in the reestablishment of a large acreage of wetlands (ca. 1500 acres, according to Tables 2-10 and 2-11).	The Record of Decision prepared by DOE on this EIS will present the alternatives DOE considered in reaching its decision and will specify the alternative(s) that were considered to be environmentally preferable.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
A0-2	Although the estimated costs of construction are higher for recirculating towers than for once-through cooling towers for C- and K- Reactors (\$153 million vs. \$92-109 million), the estimated operating costs for recirculating towers for both reactors is considerably less (\$1 million per year vs. \$3.8-6.2 million per year). The additional outlay required for construction of recirculating towers would be paid for in 8.5 to 22 years in savings generated by lower operating costs. Thereafter the operation of recirculating towers would save \$2.8-5.2 million per year. (Calculations are based on data provided in Tables 2-10 and 2-11.)	The operating life of the reactors is assumed to be 15 years after cooling towers are built. The calculations in comment A0-2 do not include the greater production loss for recirculating cooling towers than for once-through cooling towers. The life cycle costs which include capital expenditure, operating costs, and production losses indicate that a gravity-fed natural draft once-through cooling tower is most economical. Also see response to comments AD-1 and BC-5 for cost components and present worth analysis.
A0-3	<i>The alternatives for D-Area, increased flow with mixing or direct discharge to the Savannah River, are more difficult to evaluate. The preservation of habitat for the American alligator and wood stork which would result from the alternative of "increased flow with mixing" perhaps outweighs the complete elimination of all thermal discharges to Beaver Dam Creek which would result from "direct discharge to the Savannah River."</i> In any event I strongly recommend that recirculating towers be constructed for C- and K- Reactors and that one of the two alternatives -- increased flow with mixing or direct discharge to the Savannah River -- be implemented for D-Area. I appreciate being given an opportunity to comment on the DEIS. Yours very truly, William D. Anderson, Jr. Professor of Biology WDA/fb	See response to comment A0-1.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	STATEMENT OF BRUCE RIPPETEAU	
	University of South Carolina Columbia, S.C. 29208	
	The South Carolina Institute of Archaeology and Anthropology (803) 777-8170	
	April 22nd, 1986	
	Mr. R. P. Whitfield, Director, Environmental Division, U. S. Department of Energy, Savannah River Operations Office, Post Office Box A, Aiken, SC 29802	
	<u>RE: EIS-8604-008</u>	
	Dear Mr. Whitfield	
AP-1	I have received and reviewed your Draft Environmental Impact Statement, Alternative Cooling Water Systems, Savannah River Plant EIS-8604-008. I would like to congratulate you and your Department of Energy and Savannah River Plant staff on its quality. The document is an excellent example of the proper attention to both archaeological and historical resources under the provision of an environmental impact statement. Since the archaeological studies were completed by the Savannah River Plant Archaeological Resource Program staff in an ongoing contract arrangement with us at the South Carolina Institute of	Comments noted.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	Archaeology & Anthropology at the University of South Carolina, I will not comment on this portion of the statement. An independent state agency review will be made by the South Carolina Department of Archives & History, in their capacity as the State Historic Preservation Officer, commenting under Federal Regulation to the Department of Energy. I await their comments with interest. Sincerely, Bruce Rippeteau, Director, State Archaeologist BER/mn cc: Mr. Danny Cromer, State Clearinghouse, Mr. Glen Hansen, Head, SRP Archaeological Resources Program Dr. Charles Lee, State Historic Preservation Officer	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
STATEMENT OF J. LEONARD LEDBETTER		
	Georgia Department of Natural Resources 205 Bulter Street, S.E., Suite 1252, Atlanta, Georgia 30334 J. Leonard Ledbetter, Commissioner 404/656-3500	
	May 5, 1986	
	Mr. R. P. Whitfield, Director Environmental Division U. S. Department of Energy Savannah River Operations Office P. O. Box A Aiken, South Carolina 29802	
	Re: Draft Environmental Impact Statement Alternative Cooling Water Systems Savannah River Plant	
	Dear Mr. Whitfield:	
AQ-1	We have reviewed this draft EIS dated March 1986. Although Georgia is concerned with any activity which can affect the Savannah River, most of the thermal effects from the Savannah River Plant cooling water discharges occur in South Carolina, and these discharges are regulated by the South Carolina Department of Health and Environmental Control (SCDHEC). Therefore, we will not make specific recommendations among the alternatives considered. We do expect that the Department of	The Department of Energy prepared this environmental impact statement to fulfill requirements pursuant to the National Environmental Policy Act--as identified in the current Consent Order with the South Carolina Department of Health and Environmental Control--in attaining compliance with South Carolina's Class B water classification standards.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	Energy will cooperate with the SCDHEC in taking all necessary action to protect water quality in the Savannah River and to maintain a healthy ecological system. Sincerely, J. Leonard Ledbetter Commissioner JLL:mck:036 cc: Robert G. Gross	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
STATEMENT OF RICHARD W. RILEY State of South Carolina Office of the Governor Richard W. Riley Post Office Box 11450 Governor Columbia 29211 May 8, 1986 The Honorable John S. Herrington Secretary of Energy United States Department of Energy Room 7A-257 1000 Independence Avenue, SW Washington, D.C. 20585 Dear Secretary Herrington:		
AR-1	I am writing to express my support for the Draft Environmental Impact Statement (EIS) on alternative cooling water systems for the Savannah River Plant. The cooling towers proposed in the Draft EIS should properly protect the region's water supply, and comply with federal and state laws and regulations. My staff has informed me that recycling cooling towers are preferable from a natural resource management standpoint, as less water would be drawn from the Savannah River and less habitat would be flooded in the Steel Creek basin. However, other cooling tower alternatives would also be acceptable. I am pleased that state and federal officials can agree on the need for alternative cooling water systems. Such cooperation should enable private	Comments noted.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	developers to more clearly see the need to follow state and federal laws when other portions of the Savannah River Basin are developed. Yours sincerely, Richard W. Riley RWR:bd cc: Mr. R. Lewis Shaw Mr. R. P. Whitfield	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
STATEMENT OF RICHARD O. HEGG		
Clemson University		
College of Agricultural Sciences Department of Agricultural Engineering		
May 14, 1986		
Mr. R. P. Whitfield, Director Environmental Division US-DOE, SRP Office P.O. Box A Aiken, SC 29802		
Dear Mr. Whitfield:		
AS-1	I am writing to request that DOE-SRP evaluate the feasibility of using the cooling water from the C and K reactors for agricultural purposes. After discussions with several persons at Clemson University, DOE in Washington, S.C. Commissioner of Agriculture, and others, it certainly seems worth making an evaluation to assess the legal, technical, and economic feasibility of such a project. S.C. agriculture is very depressed presently and will probably continue to be so in the near future. This resource (400,000 gpm of warm water) could be used by agriculture to increase crop yields or make it possible to grow alternative crops that will give a higher net return to the farmers. There are many factors that need to be considered. Legal aspects such as land application of water which may contain some radioactive contamination, SCDHEC requirement that water be cooled to 90°F or within 5° of ambient at the plant, consumptive use, and interbasin transfer of water for irrigation,	DOE prepared a new appendix in this EIS (Appendix I) to address the feasibility of using the cooling water discharges from K- and C-Reactors for agricultural and aquacultural uses, industrial applications, direct power generation, and ethanol production.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	etc. have to be addressed. It is also necessary to evaluate the effects of the reactors being periodically shut down. This will impact the types of crops grown and whether a backup irrigation water supply is needed. During winter some other use, such as greenhouses or aquaculture, may be an ideal way to utilize the water. A major assessment of social and economic factors involved will be needed. If such a source of water is made available to agriculture, an organization would need to be formed to distribute, maintain, operate, allocate water, etc. for the system. Makeup and operation of such an organization would have to be developed with input from Federal, state, and county officials and the ultimate user, the farmer. The cost of constructing various phases of such a project would have to be estimated. Costs would include distribution canals or pipes, pumps, meters, roads, bridges, etc. The environmental impacts on crops, soil, wildlife, surface and groundwater would also need to be evaluated. The above items are a few of many that need to be included in such a feasibility study. Due to the size of the resource (cooling waer) and the needs of S.C. agriculture, I feel a study should be made and estimate the cost of a 6-9 month study at approximately \$150,000. This should be done by	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	DOE-SRP as part of the EIS with input from Clemson scientists in the College of Agricultural Sciences and other state agencies.	
	Sincerely,	
	Richard O. Hegg, Head Agricultural Engineering Department	
	lw	
	xc: Lee Thomas, Administrator, US-EPA L. P. Anderson, Dean, College of Agriculture, Clemson University Admiral Foley, DOE, Washington, DC Les Tindal, S.C. Commissioner of Agriculture Senator Strom Thurmond Senator Ernest Hollings Representative Carroll Campbell Representative Butler Derrick	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	STATEMENT OF CHARLES E. LEE South Carolina Department of Archives and History 1430 Senate Street Columbia, S.C. P. O. Box 11,669 Capitol Station 29211-1669 803-758-5816 May 9, 1986 Dr. Robert J. Stern U.S. Department of Energy Office of Environmental Guidance (EH-23) Room 3G-092 Forrestal Building 1000 Independence Ave., SW Washington, D.C. 20585 Re: Draft EIS Alternative Cooling Water Systems Savannah River Plant EIS-8604-008 Dear Dr. Stern: Thank you for the opportunity to review and comment on the Draft EIS for the proposed Alternative Cooling Water Systems at the Savannah River Plant in South Carolina. A copy of the Draft EIS was provided to us by the State Clearinghouse. As the State Historic Preservation Office, our concern is whether the proposed project will have an effect on cultural resources eligible or potentially eligible for inclusion in the National Register of Historic Places. The cultural resources survey for those areas affected by the	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	cooling water discharge of the C- and K-Reactors and the D-Area has been provided to us under separate cover by the Savannah River Plant.	
AT-1	We note that 65 archaeological sites were identified along the banks of Beaver Dam and Four Mile Creeks and Pen Branch; we concur with the assessment of National Register eligibility for 23 of these archaeological sites. Since these National Register eligible sites will not be directly affected by construction of the alternative water cooling systems at the C- and K-Reactors and the D-Area, it is our opinion that the construction presently proposed will have No Adverse Effect on National Register eligible sites. Our determination of No Adverse Effect is contingent on the condition that the discharge water levels into Beaver Dam and Four Mile Creeks and Pen Branch be monitored on a regular basis to ensure that these significant cultural resources are not affected by inundation and/or erosion.	DOE, as part of its monitoring program of the onsite streams, will monitor flows in Beaver Dam, Four Mile, and Pen Branch Creeks on a regular basis. Should evidence of erosion occur on any archaeological site, DOE will notify the SHPO.
AT-2	If the Department of Energy concurs with the SHPO's determination of Conditional No Adverse Effect, then the Advisory Council on Historic Preservation should be provided the opportunity to comment. A copy of this letter should be included as evidence of DOE's consultation with the SHPO. The Federal regulations for the protection of historic properties (36 CFR Part 800) require that the Federal agency official in charge of a federally funded or licensed project consult with the appropriate State Historic Preservation Officer. The regulations do not relieve the Federal agency official of the final responsibility for reaching an opinion of his own as to whether or not historic values have been taken into account in allowing the project to proceed. The opinion of	A letter of concurrence has been received from the Advisory Council on Historic Preservation. See comment AZ-1 concerning the no objection to a determination of "no effect" from the Advisory Council on Historic Preservation.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	the State Historic Preservation Officer is not definitive, either by law or by established Federal procedure. In reaching a conclusion of his own, the Federal agency official may well wish to consult other experts. The above comments are made in accordance with Section 106 of the National Historic Preservation Act and the regulations codified at 36 CFR Part 800. If you have questions, please do not hesitate to contact Ms. Nancy Brock, Environmental Review Specialist, or Ms. F. Langdon Edmunds, Historic Preservation Protection and Planning Head, at (803) 758-5816. Sincerely, Charles E. Lee State Historic Preservation Officer cc: Mr. R. P. Whitfield Savannah River Plant Mr. Glen Hanson SCIAA Mr. Danny Cromer State Clearinghouse Ms. Trish Jerman Office of Energy and the Environment Mr. Ron Anzelone Advisory Council Dr. Bruce E. Rippeteau State Archaeologist	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
STATEMENT OF DANNY L. CROMER		
	State of South Carolina Office of the Governor	
	Richard W. Riley Governor	Office of Executive Policy and Programs
	May 15, 1986	
	Dr. Robert J. Stern Director Office of Environmental Guidance United States Department of Energy Room 3G-092 1000 Independence Avenue, S.W. Washington, D. C. 20585	
	Dear Dr. Stern:	
	The South Carolina Project Notification and Review System (SCPNRS) has conducted an intergovernmental review on the Draft Environmental Impact Statement on Alternative Cooling Water Systems at the Savannah River Plant in Aiken, South Carolina. The intergovernmental review was conducted through the review system established under the authority of Presidential Executive Order 12372, "Intergovernmental Review of Federal Programs". All comments received by this office are enclosed for your use.	
AU-1	While no correspondence has been received indicating this direct federal development is not subject to Department of Energy intergovernmental review regulations promulgated at 10 CFR Part 1005, this office assumes the proposed activity is exempt	DOE is exempt from intergovernmental review regulations by virtue of national security considerations.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
AU-2	from the referenced regulations by virtue of national security considerations. If this assumption is incorrect, please advise. The only comment received by this office expressing a concern regarding the referenced Draft EIS is from the South Carolina Department of Archives and History. Therefore, the regular monitoring of discharge water levels into Beaver Dam and Four Mile Creeks and Pen Branch is strongly encouraged, as per the enclosed conditional determination of No Adverse Effect from the South Carolina Department of Archives and History. The State Application Identifier number for this project is EIS-8604-008. This number should be used in any future correspondence with this office regarding this proposal. The State of South Carolina is appreciative of the opportunity to review this proposed activity, and looks forward to reviewing the Final EIS upon its completion. If I may answer any questions, or be of further service in any way, please do not hesitate to contact me at (803) 758-2417. Sincerely, Danny L. Cromer State Single Point of Contact Intergovernmental Review Enclosures	See response to comment AT-1.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
cc:	Mr. R. P. Whitfield Savannah River Plant Ms. Suzanne Rhodes Governor's Division of Energy and the Environment Mr. Charles Lee South Carolina Department of Archives and History	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
STATEMENT OF HILARY J. RAUCH Department of Energy Chicago Operations Office 9800 South Cass Avenue Argonne, Illinois 60439 May 20, 1986 R. P. Whitfield, Director Environmental Division Savannah River Operations Office SUBJECT: SAVANNAH RIVER PLANT DRAFT ENVIRONMENTAL IMPACT STATEMENT (EIS), "ALTERNATIVE COOLING WATER SYSTEMS" - AIKEN, SOUTH CAROLINA (DOE/EIS-0121D)		
AV-1	We have reviewed the subject document to identify any items to be addressed at the upcoming hearing or incorporated in the final EIS. We have no comments. Thank you for the opportunity to review the document. If you have questions, contact Jerry Nelsen, Operational and Environmental Safety Division, on FTS 972-2256. Hilary J. Rauch Manager	Comments noted.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
STATEMENT OF THOMAS F. HARTNETT		
Congress of the United States House of Representatives Washington, DC 20515		
May 8, 1986		
The Honorable John S. Herrington Secretary of Energy 1000 Independence Ave. SW Washington, D.C. 20585		
Dear Mr. Secretary:		
AW-1	I am writing in regard to the possibility of alternative uses for the cooling water from nuclear reactors at the Savannah River Plant. As you know, Senator Thurmond recently sponsored a meeting that produced an open discussion among several of the principals who are considering the viability of these alternative uses. Mr. Fred Christensen, a participant of the meeting and a retired engineer at the Savannah River Plant, remained quite dismayed at the reaction by the representatives of the Department of Energy toward his ideas for usage of the cooling water. Specifically, he stated that he could not understand why \$100 million can be set aside for the construction of cooling towers, but one tenth of one percent of this amount cannot be allocated for a study into the effectiveness of alternative applications for the cooling water. Therefore, for my own clarification, I would greatly appreciate hearing your response to Mr. Christensen's proposal to study the logistics of irrigation as an option to heat abatement.	DOE prepared a new appendix in this EIS (Appendix I) to address the feasibility of using the cooling water discharges from K- and C-Reactors for agricultural and aquacultural uses, industrial applications, direct power generation, and ethanol production.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	As always, thank you for your time and consideration. With kind regards, I am	Sincerely, Thomas F. Hartnett, M.C.
TFH/bu		

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
STATEMENT OF BUTLER DERRICK		
Congress of the United States House of Representatives Washington, D.C. 20515		
May 14, 1986		
Mr. R.P. Whitfield, Director Environmental Division U.S. Department of Energy Savannah River Operations Office Post Office Box A Aiken, South Carolina 29802		
Dear Mr. Whitfield:		
This is in reference to the recently issued Draft Environmental Impact Statement (DEIS) concerning Alternative Cooling Water Systems, Savannah River Plant, Aiken, South Carolina (DOE/EIS-0121D).		
At the outset, let me note that I am pleased to learn that the Department of Energy (DOE) is moving forward to implement alternative cooling water systems in order to bring the C and K production reactors at the Savannah River Plant (SRP) into compliance with the National Pollutant Discharge Elimination System (NPDES) permit issued by the South Carolina Department of Health and Environmental Control (DHEC). I appreciate receiving a copy of the DEIS for review of this matter.		
AX-1	During the recent public hearings in Aiken, South Carolina, on this DEIS, I understand several witnesses addressed the issue of potential uses of the water discharged from the C and K reactors for	DOE prepared a new appendix in this EIS (Appendix I) to address the feasibility of using the cooling water discharges from K- and C-Reactors for agricultural and

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	agricultural purposes such as irrigation. Moreover, this is an option which has been publicly discussed for several years, although no formal studies have been undertaken recently to fully evaluate the merits of the proposal. My purpose is writing, therefore, it to suggest that a full evaluation of potential agricultural uses of this discharge water, particularly for irrigation purposes, be undertaken as part of your review of alternatives to mitigate the environmental impacts of the thermal discharges as mandated by the National Environmental Policy Act of 1969. Specifically, I request that a Supplemental Draft Environmental Impact Statement be issued on this proposal, which is a significant alternative to the proposed mitigation presented in your DEIS. It is my understanding that a meeting was recently held in Washington, D.C. with the Assistant Secretary for Defense Programs, Department of Energy (DOE). While this meeting was conducted at the staff level (a member of my staff was in attendance) it is my understanding that the general consensus from the meeting was that the potential agricultural uses of this waste water warranted further and comprehensive study. Moreover, I am not in a position to evaluate nor pass on the technical, health and environmental safety aspects of this proposal. I believe, however, that the Department of Energy is in a unique position to supply the requisite personnel and resources to preform a full analysis of this subject. And the Environmental Impact Statement process is the logical framework in which to conduct such a study.	aquacultural uses, industrial applications, direct power generation, and ethanol production.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	Thank you for your time and consideration in the above. Please let me know if I may be of further assistance to facilitate your review of this matter. With kindest regards, I am,	Respectfully, Butler Derrick Member of Congress
D/ht		

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
STATEMENT OF JOHN C. VILLFORTH		
	Department of Health & Human Services Public Health Service Food and Drug Administration Rockville MD 20857 May 19, 1986 Mr. R. P. Whitfield Director, Environmental Division Department of Energy Savannah River Operations Office P.O. Box A Aiken, South Carolina 29802 The Center for Devices and Radiological Health staff has reviewed the Draft Environmental Impact Statement (DOE/EIS-0121 D) on Alternative Cooling Water Systems, Savannah River Plant, dated March 1986. Our effort is primarily directed to an evaluation of the public health and safety impacts associated with the proposed alternative cooling water systems for C- and K- reactors and the D-area coal-fired powerhouse. We have the following comments to offer:	
AY-1	1. The discussion in Chapter 4 and Appendix D have adequately assessed the radiological releases to the environment and the potential impact on individual and population dose for cooling water alternatives for the C- and K- reactors. There is no impact for cooling water alternatives for the D- area since there are no radiological releases.	Comments noted.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
2.	The environmental pathways identified in Appendix G (Figure G-1) cover all possible emission pathways that could impact on the population in the environs of the Savannah River Plant. The radiation dose calculation methods and assumptions presented in Appendix D have provided reasonable estimates of annual dose to the maximally exposed individual and collective dose to the population within the 80-kilometer area from operation of alternative cooling water systems for the C- and K-reactors. Results of these calculations are shown in Appendix D, Tables G-7 through G-38, and indicate that the doses are minimal and are well within current radiation protection standards.	
3.	It appears from our review of this Draft Environmental Impact Statement that the radiological dose changes are not significant compared with the doses resulting from existing operations. Thus, because of these low radiation related impacts, it is concluded that either once through cooling towers or recirculating cooling towers would be acceptable and that the choice of alternatives should not be based on radiological considerations. We believe that this conclusion is valid from a public health and safety viewpoint and is justified by the technical assessment of the radiological impact.	

Thank you for the opportunity to review and comment on the Draft Environmental Impact Statement.

Sincerely,

John C. Villforth
 Director
 Center for Devices and
 Radiological Health

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
STATEMENT OF DON L. KLIMA		
	Advisory Council on Historic Preservation The Old Post Office Building 1100 Pennsylvania Avenue, NW, #809 Washington, DC 20004 May 21, 1986 Mr. R. P. Whitfield Director, Environmental Division Department of Energy Savannah River Operations Office P.O. Box A Aiken, SC 29802 REF: Draft Environmental Impact Statement, Alternative Cooling Water Systems Savannah River Plant, Aiken, South Carolina Dear Mr. Whitfield:	
AZ-1	We have reviewed the referenced document, including its Appendix E. The discussion of historic and archeological properties and effects on them appears thorough and complete. Based on the information provided, we would have no objection to a determination of "no effect" for Archeological site 38BR450 in relation to any increased flows in the Beaver Dam Creek (D-Area) under that alternative of the cooling water systems being considered. Please ensure that the South Carolina State Historic Preservation Officer has no	Comments noted. The South Carolina State Historic Preservation Officer concurs with the "no effect" determination. See comments AT-1 and AT-2.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	objection to such a determination. In the event he does, further discussions with the Council would be necessary. 1 We appreciate your continued cooperation on the various projects at the Savannah River Plant. Should you or your staff have any questions, please contact Staff Archeologist Ronald D. Anzalone at 202-786-0505 (an FTS number). Sincerely, Don L. Klima Chief, Eastern Division of Project Review	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
STATEMENT OF DAN M. MAULDIN		
	Department of the Army South Atlantic Division, Corps of Engineers 510 Title Building, 30 Pryor Street, S.W. Atlanta, Georgia 30335-6801 May 19, 1986 Reply to Attention of: Planning Division SUBJECT: Cooling Water EIS Mr. R. P. Whitfield Director, Environmental Division U.S. Department of Energy Savannah River Operations Office Post Office Box A Aiken, South Carolina 29802 Dear Mr. Whitfield: This is in response to your letter of March 28, 1986, to Brigadier General C. E. Edgar III requesting our review of the Draft Environmental Impact Statement, Alternative Cooling Systems, Savannah River Plant, Aiken, SC (DOE/EIS-0121D). We have reviewed the document and offer the following comments: a. While we may understand the reasons for eliminating the alternative of cooling ponds, it may not be as readily apparent to other readers. It is suggested that a more detailed account of discussing engineering, economic,	
BA-1		DOE initially identified 22 possible alternative cooling water systems that would

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
b.	and environmental reasons for dropping the alternative be provided. For example, the high cost of preparing the dam foundation, the wetland habitat loss involving an endangered species, the fact that DOE is already compensating for habitat loss due to Steel Creek Dam, and the operational constraints imposed by a cooling pond are all factors which should be discussed as affecting the choice of the alternative. Appendix A does not fully convince the reviewer that dams are not a viable option. Further explanation should be provided.	be implemented for K- and C-Reactors and four alternatives for the D-Area powerhouse. Subsequently, using a structured screening process, DOE identified those that would be reasonable to implement. The screening process, which included detailed engineering, economic and environmental assessments of each alternative, was documented in the <u>Thermal Mitigation Study</u> (DOE, 1984) that was submitted to SCDHEC under Consent Order and subsequently approved. Appendix A is a synopsis of the detailed screening process provided in the <u>Thermal Mitigation Study</u> and provides a brief rationale for alternatives that were considered in the EIS. Appendix A references the <u>Thermal Mitigation Study</u> (DOE, 1984) for a detailed evaluation of alternatives.
	The opportunity to review the document is appreciated. Sincerely, John W. Rushing for Dan M. Mauldin Chief, Planning Division	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
STATEMENT OF JAMES A. JOY, III		
South Carolina Department of Health and Environmental Control		
2600 Bull Street Columbia, S.C. 29201	Board Moses H. Clarkson, Jr., Chairman Gerald A. Kaynard, Vice-Chairman Oren L. Brady, Jr., Secretary Barbara P. Nuessle James A. Spruill, Jr. William H. Hester, M.D. Euta M. Colvin, M.D.	
Commissioner Robert S. Jackson, M.D.		
June 6, 1986		
W. E. Wisenbaker Department of Energy Savannah River Operations Office P.O. Box A Aiken, S.C. 29802	Re: Draft Environmental Impact Statement (DEIS) Alternative Cooling Water Systems Savannah River Plant - General	
Dear Mr. Wisenbaker:		
The South Carolina Department of Health and Environmental Control has completed its review of the above referenced document received March 31, 1986. The Department has the following comments concerning the DEIS.		

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
BB-1	1. The impact of total residual chlorine on the receiving stream needs to be further discussed because it may effect the alternative selected (i.e., dechlorination vs ponds after the cooling towers). It should be noted that the Ambient Water Criteria for Chlorine Document (EPA/5-40-030) recommends a total residual chlorine of 11 ug/l for an instream concentration. Since the reactor cooling water is basically the stream, the discharge of these waters would need to meet 11 ug/l. If it is felt by SRP that a higher total residual chlorine is warranted other than that above, we would like this topic to be further discussed and justified in the FEIS. It should be noted that a mixing zone other than immediately at the outfall will not be considered.	DOE plans to dechlorinate K- and C-Reactor cooling waters prior to discharge from the cooling towers to onsite streams. Discussion of the method to be used and an assessment of the potential impact based on the results of chlorination/dechlorination studies conducted at SRP have been included in Chapter 4 with additional support information provided in Appendix C of the FEIS.
BB-2	2. Does SRP plan to use corrosion inhibitory compounds and/or additional biocides other than chlorine in the cooling towers, and if so, how will they affect the receiving stream? As stated above since the reactor cooling water is basically the stream, a small amount of a biocide in the cooling water discharge may have a detrimental impact to the stream.	Once-through cooling tower systems would not use corrosion inhibitors. Allowance for injection of a corrosion inhibitor has been made for recirculating systems. A non-chromated, organic-based chemical made by Wright Chemical Company would be used if needed. Currently, this chemical is approved by SCDHEC for use in cooling tower systems and is being used at the Savannah River Plant.
	3. The Department has advised you previously in a letter dated March 4, 1985 that both recirculating cooling towers and once through cooling towers satisfy state standards. We also stated that for the alternatives chosen in the Thermal	Chlorine is the only biocide planned for use in the cooling towers.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	Mitigation study that 316(a) studies would need to be developed and implemented to assure that the rise above ambient stream temperature (t) would not adversely impact the receiving stream. In further review of the DEIS some concerns have surfaced from this office on whether or not once-through cooling towers are capable of demonstrating a successful 316(a) study. The streams to which the reactor cooling water will discharge are Class B waters. The Water Classification and Standards (Reg. 61-68) for Class B waters concerning temperature state: "The water temperature of all...Class B free flowing waters shall not be increased more than 5°F (2.8°C) above natural temperature conditions or exceed a maximum of 90°F (32.2°C) as a result of the discharge of heated liquids unless a different temperature standard as provided for in Section E. has been established, a mixing zone as provided in D.(5) has been established, or a Section 316(a) determination under the Federal Clean Water Act has been completed." Since the delta 5°F (2.8°C) requirement cannot be met SRP plans to conduct a 316(a) study. In order for this study to be successful SRP must demonstrate that under the operating conditions of the once through cooling towers the receiving stream can meet the requirements for a Class B stream. The Class B requirements are (Regulation 61-68 E.5). CLASS B - freshwaters suitable for secondary contact recreation and as a source for drinking	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	water supply after conventional treatment in accordance with the requirements of the Department. Suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. Suitable also for industrial and agricultural uses.	
BB-3	Based on our further investigation and discussions with EPA, it is felt that SRP may not be able to demonstrate that indigenous species are able to reproduce in the receiving stream due to elevated temperatures. Therefore, if SRP should propose any alternative cooling technology which would require a 316(a) variance, it will be necessary that the Final Environmental Impact Statement (FEIS) provide predictive biological data which substantiates a reasonable probability that Section 316(a) requirements can be achieved.	Substantive Section 316(a) Demonstration - type information relating to K- and C-Reactors and the D-Area powerhouse has been included in Chapter 4 of the FEIS and a complete predictive Section 316(a) Demonstration will be provided to SCDHEC at an agreed-to date. In addition, per Consent Order No. 84-4-W between DOE and SCDHEC, if the selected cooling water systems discharge temperature does not comply with the 2.8°C T above ambient temperature requirement, DOE will conduct Section 316(a) Demonstration studies to assess directly during plant operations whether thermal discharge conditions will ensure the protection and propagation of balanced indigenous populations of fish and wildlife in the affected areas.
BB-4	4. In the May 20th meeting attended by SRP, EPA, and DHEC personnel concerning the DEIS, SRP personnel described the sequence of events for reactor shut downs. The reactor shuts down for a five day period after every 30 days of operation, along with a 20 day shut down after every sixth cycle. This office feels that this flow variation may cause detrimental effects on the receiving stream and feels the FEIS should further discuss the flow variation and shut	See response to comment BB-3. Potential impacts from reactor shutdown and the associated flow variability have been addressed in Chapter 4 of the FEIS.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	down effects on the aquatic habitat. It is felt that the above should be addressed in the predictive biological data requested to be provided in the FEIS.	
BB-5	5. This office would also like predictive biological data to be in the FEIS for the <i>D-area powerhouse</i> which would substantiate a reasonable probability that Section 316(a) requirements can be achieved. <i>In conclusion, the recirculating cooling tower alternative as expressed in the DEIS appears capable of meeting the state standards. However, the once through cooling tower alternative needs to be further discussed in the FEIS, specifically whether or not the once through cooling tower alternative is capable of demonstrating a successful 316(a) study.</i> Based on the information provided in the DEIS we feel recirculating cooling towers for C and K reactors will provide a higher degree of certainty of meeting the state stream standards than that of the once through cooling tower alternative. We appreciate the extra time you have given us to comment on the DEIS and if you would like to discuss the above comments please call (758-5483). Sincerely, James A. Joy, III, P.E., Director Industrial & Agricultural Wastewater Division	Substantive Section 316(a) Demonstration - type information relating to the D-Area powerhouse has been included in Chapter 4 of the FEIS. In addition, a complete predictive Section 316(a) Demonstration will be provided to SCDHEC at an agreed-to date. Should the selected cooling water systems discharge temperature not comply with the 2.8°C rise above ambient temperature criterion, Section 316(a) Demonstration studies will be conducted during plant operations to assess directly whether the protection and propagation of balanced indigenous populations of fish and wildlife are maintained in the affected areas. The Record of Decision prepared by DOE on this EIS will present the alternatives DOE considered in reaching its decision and will specify the alternative(s) that were considered to be environmentally preferable.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
JAJ/JBR/jf	cc: Kin Hill, Lower Savannah Russ Sherer, Division of Water Quality & Enforcement Mike Marcus, Biological Section Harry Gaymon, Biological Section John Marlar, EPA	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
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STATEMENT OF JACK E. RAVAN

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IV
345 Courtland Street
Atlanta, Georgia 30365

June 12, 1986

4 PM - EA/HJM

Mr. R. L. Morgan
Department of Energy
Savannah River Operations Office
P.O. Box A
Aiken, South Carolina 29802

SUBJECT: DEIS for Alternative Cooling Water
Systems, Savannah River Plant, Aiken,
South Carolina

Dear Mr. Morgan:

Pursuant to our responsibilities under Section 309 of the Clean Air Act (CAA) and the National Environmental Policy Act (NEPA), the Environmental Protection Agency (EPA) has reviewed the Draft Environmental Impact Statement (DEIS) for Alternative Cooling Water Systems at the Savannah River Plant, Aiken, South Carolina. Our review has concentrated on the potential environmental impacts on water and air quality, wetlands, aquatic habitat and radiological considerations of the proposed alternatives. The purpose of the DEIS document is to assess the relative impacts of various alternative ways to comply with the discharge temperature limitations for the on-site streams. The document covers the discharge from the C-Reactor, the K-Reactor and the D-Area coal-fired power plant.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	For both of the reactors, two primary alternatives are proposed: once-through cooling (subsequently referred to as "helper cooling" herein) and recirculating cooling (referred to as "closed-cycle cooling" herein). For the D-Area power plant, direct discharge to the Savannah River and increased flow with continued discharge to Beaver Dam Creek were the alternatives considered. Although all the proposed action alternatives are a major improvement over existing conditions, our review has identified several areas of major concern which must be addressed in the Final Environmental Impact Statement (FEIS) before an alternative can be selected. In formulating our comments we have met with the SRP staff on two occasions to discuss our concerns and have coordinated our review with the South Carolina Department of Health and Environmental Control (SCDHEC) and the U.S. Fish and Wildlife Service (USFWS).	
BC-1	Should DOE continue to prefer an alternative cooling technology which would require a 316 variance, the FEIS should present predictive biological data which demonstrates a reasonable probability that Section 316 requirements can be achieved. Prior to implementation of a cooling alternative, it will be necessary for DOE to assure that the system will achieve compliance with water quality standards requirements or to obtain a variance to those standards under Section 316(a) of the Clean Water Act.	See response to comment BB-3.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	A summary of additional areas of concern follow (a more complete discussion is contained in the attached "Detailed Comments"). • The high sedimentation levels and the resultant stream delta growth expected from the helper cooling alternative would continue to adversely impact vegetated wetlands and aquatic habitat. • The requirements for biocides and corrosion inhibitors for the cooling system alternatives and their potential impacts on the aquatic community were not addressed in adequate detail in the DEIS. <u>Conclusions</u> EPA's review of the DEIS has identified a number of major environmental concerns which need to be addressed in the FEIS before a final alternative can be selected for implementation. These concerns relate directly to the alternatives ability to meet water quality standards or obtain a variance under Section 316(a), and thus be environmentally acceptable and permitable. To provide a technical basis for resolving our concerns additional information should be provided in the FEIS for a number of areas including:	
BC-2	• Predictive biological data for alternatives requiring a 316(a) variance;	See response to comments BB-3 and BB-5.
BC-3	• The results of the proposed Habitat Evaluation Procedure (HEP);	A HEP analysis was conducted for the habitats of the receiving streams. The results of this analysis are presented in Chapter 4 and Appendix C; the complete report is available at DOE Public Reading Rooms in Aiken, South Carolina, and Washington, D.C.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
BC-6	A present worth analysis of the considered alternatives to provide a common basis for comparing capital, operating and production costs.	Costs in the draft EIS were based on preliminary engineering information used for the alternatives listed on pages 2-43 and 2-50 of the draft EIS. Revised costs shown below reflect additional engineering studies; they are also included in Comparison of Alternatives (Section 2.3) of the FEIS. For the conceptual designs evaluated, the estimated production loss for a once-through cooling water system is about 0.2 percent, and that for a recirculation system is about 3.7 percent. Present worth was calculated using the following parameters: 15 year life; 10 percent discount rate; 6.2 percent escalation; power cost \$47.50/MW-hr.; and reactor cost \$300,000/day. A 15 year life is assumed for the current reactors. For recirculating cooling water systems the costs include the decrease in electricity use (i.e., a savings) because much less water is pumped from the river. <u>C-AREA</u> <u>Gravity Flow Mechanical Draft, once-through system</u> - Present worth excluding production losses \$60,300,000 - Present worth including production losses \$64,300,000 <u>Pumped Flow Mechanical Draft, once-through system</u> - Present worth excluding production losses \$81,400,000 - Present worth including production losses \$86,000,000

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
BC-4	Further assurances that the cooling tower design will be able to achieve the projected discharge temperatures;	Cooling-tower performance and sizing calculations were based on once-through operations. The temperatures of water directed from an SRP reactor into a cooling tower is much higher than for steam-electric generating plants. Therefore, Du Pont employed a cooling-tower consultant and contacted cooling-tower vendors to discuss sizing and performance of potential towers for the SRP's unusually high inlet temperature with low approach temperature. In addition, the specification for production losses were "less than 10 percent" for a once-through system and "approximately 4 percent" for a recirculating system. The request for bids from cooling-tower vendors is based on a performance specification. It is the vendor's responsibility to design and build a tower that will meet or exceed the performance specifications. The contract with the successful bidder will include liquidated damages for failure of the tower to meet the performance specified. Based on current information and planned contract negotiations, Du Pont is confident the cooling towers will operate as stated in the EIS.
BC-5	A more in-depth evaluation of water chemistry requirements (biocides and corrosion inhibitors) and their possible air and water quality impacts; and	See response to comments BB-1 and BB-2.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
		• <u>Pumped Flow Mechanical Draft, recirculating system</u> - Present worth excluding production losses \$65,800,000 - Present worth including production losses \$97,600,000
		<u>K-AREA</u>
		• <u>Gravity Flow Mechanical Draft, once-through system</u> - Present worth excluding production losses \$59,000,000 - Present worth including production losses \$63,300,000 • <u>Pumped Flow Mechanical Draft, once-through</u> - Present worth excluding production losses \$80,400,000 - Present worth including production losses \$86,000,000 • <u>Pumped Flow Mechanical Draft, recirculating</u> - Present worth excluding production losses \$65,800,000 - Present worth including production losses \$97,600,000
		Although estimated costs for gravity-flow, once-through natural draft towers were not shown in the draft EIS, the estimates since developed are:

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
		<u>C-AREA</u>
		• <u>Gravity Flow Natural Draft, once-through system</u> - Present worth excluding production losses \$42,400,000 - Present worth including production losses \$44,000,000
		<u>K-AREA</u>
		• <u>Gravity Flow Natural Draft, once-through system</u> - Present worth excluding production losses \$41,400,000 - Present worth including production losses \$43,000,000 Below are estimated costs for a gravity flow natural draft tower with pumped feed to a mechanical draft tower in a recirculating mode that was developed after the draft EIS was completed and is explained in greater detail in Chapter 2 of this Final EIS:
		<u>C- and K-AREAS</u>
		• <u>Recirculating System</u> - Present worth excluding Production losses 58,000,000 - Present worth including Production losses \$89,800,000

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	This additional information is important in assessing the impact of the proposed alternatives on the natural environment for the expected life of the project. In addition, EPA feels strongly that the NEPA process is the appropriate means of identifying and addressing any major permitting issues such as the Section 316(a) variance question. Only in this manner can an alternative be selected that both addresses environmental impacts and can successfully achieve permit requirements. Based on our review, EPA rates the Draft Environmental Impact Statement for the Alternative Cooling Water Systems an EO-2 (i.e, significant issues have been identified relative to the preferred alternative being able to meet water quality standards thermal criteria, which may require substantial modification of the alternative or consideration of other alternatives). Also, as discussed above, the FEIS should contain the additional requested information as well as addressing the DEIS comments. My staff will be available to meet with DOE, SCDHEC and USFWS in order to assist in further defining the needed studies and data. We appreciate the additional time you have given us to comment on the DEIS. We hope that through the on-going close cooperation with DOE the environmental concerns can be successfully resolved and the most acceptable	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	alternative can be identified. The primary EPA point of contact for this project is Heinz J. Mueller, (FTS) 257-7901 or (404) 347-7901. Sincerely yours, Jack E. Ravan Regional Administrator Enclosure cc: See attached cc: Mr. James A. Joy, III Director of Industrial and Agricultural Wastewater Management Division South Carolina Department of Health and Environmental Control Columbia, S.C. 29201 Mr. Roger Banks, Field Supervisor Ecological Services U.S. Fish and Wildlife Service 217 Ft. Johnson Road Charleston, S.C. 29412 ATTN: Mr. Prescott Brownell	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
DETAILED COMMENTS FOR ALTERNATIVE COOLING WATER SYSTEM DEIS Savannah River Plant, Aiken, South Carolina		
<u>Water Quality</u>		
Currently, both the C- and K-Reactor are discharging cooling water into Four Mile Creek and Pen Branch, respectively, at temperatures averaging 70° to 77°C (158° to 170.6°F). This exceeds the State of South Carolina Water Quality Standards (SCWQS) Class B criterion which specifies a maximum instream temperature of 32.2°C (90°F). Based on the calculations in the DEIS, both major alternatives being considered, helper and closed-cycle cooling, appear to meet this maximum temperature criterion. However, there are a number of areas of concern that must be addressed in the FEIS prior to selection of a final cooling system.		
BC-7	As indicated in the DEIS, the helper cooling alternative for the C- and K-Reactor will not achieve compliance with the 2.8°C (5°F) criterion allowed by the water quality standards for increases in ambient stream temperatures. During the winter and spring months projected increases will be 13 to 15°C (23.4° to 27°F) based on Table 2.1. Selection of the helper alternative would require a variance to the temperature increase criterion. Under Section 316(a) of the Clean Water Act, a permittee for an NPDES permit may obtain a variance to applicable thermal limitations if a demonstration can be made that the applicable limitations are more stringent than necessary to "assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife, in and on that body of water."	See responses to comments BB-3 and BB-5.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
BC-8	A predictive Section 316(a) assessment will be necessary prior to NPDES permit issuance to demonstrate that the level of thermal release calculated for the helper cooling alternative (or any alternative which would not achieve compliance with applicable temperature requirements) would assure compliance with 316 requirements. Therefore, to assure that the 316(a) process proceeds without delay, it will be necessary for DOE to provide predictive biological data in the FEIS. Such data must demonstrate that discharge from the alternative proposed has a reasonable chance to achieve 316(a) requirements. That is, that reasonable reproduction of aquatic organisms will be ensured in both the receiving creeks and associated marsh areas under all discharge temperature and flow conditions resulting from all planned plant operating modes, as well as periods of normal and extended shutdown. Data on rate of creek and wetland drainage as a function of reactor shutdown and Savannah River stage will be needed in this evaluation. Data presented in the DEIS indicate that discharge temperatures predicted for the helper cooling tower system during the spring (25 to 28°C) would be high and would likely prevent the successful spawning and reproduction of many of the fish species indigenous to the Savannah River system. As indicated in "Thermal Performance" below, these predicted temperatures may be low. Even should successful spawning occur, subsequent short- or long-term shutdown of the reactor could leave the eggs or fry in a dry overbank area of the creeks or section of marsh. Additionally, longer periods of shutdown have historically been observed which might further compound this impact. In order to obtain a 316(a) variance, it will be necessary for DOE to demonstrate that these concerns are not of	See responses to comments BB-3 and BB-5.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
BC-9	significance to the propagation and protection of the aquatic community in both the free-flowing creeks and associated marshes. According to the data in the DEIS, the discharge from the closed-cycle cooling alternative for both the C- and K-Reactor would exceed the ambient stream temperature by 1°C during winter conditions while the temperature of the effluent will approach the ambient for extreme summer conditions. Use of the closed-cycle system may achieve direct compliance with water quality standards thermal limitations and no 316(a) variance would be required. Therefore, greater consideration should be given to the closed-cycle system, if the blowdown temperatures noted in Table B-1 can be achieved (see "Thermal Performance" below).	The recirculating cooling-tower systems discussed in this final EIS have been modified from those described in the draft EIS. The recirculating system in the draft EIS assumed design for 10°C wet bulb temperature and 28°C approach. This has been determined to be difficult and costly to achieve. Recirculating cooling-tower systems for alternatives now being considered are designed to achieve 29.5°C cold water temperature (CWT) at 26.7°C WBT. Wet bulb temperatures would have to exceed 29.5°C before blowdown temperatures would reach 32.2°C; basic data indicates that 27.8°C WBT was exceeded only twice during the period from 1952 through 1983. Cooling-tower performance is dependent on ambient air conditions; Savannah River water temperatures lag behind seasonal air temperature changes. If receiving stream temperature is assumed to be the same as the Savannah River and historical monthly average temperatures are used, the 2.8°C maximum allowable temperature difference between cooling-tower blowdown and receiving stream will be exceeded during the period from December through July. Maximum monthly average difference is 6.7°C in March based on recirculating cooling-tower systems designed for 26.7°C WBT with 2.8°C approach.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
BC-10	Due to the high flow rate of the helper cooling alternative, minimal reduction in the existing high level of suspended solids would be expected in the receiving creeks; especially, if the proposed holding ponds are eliminated. The closed-cycle system, however, would result in a significant reduction of suspended solids and the attendant stream/marsh sedimentation. Also see discussion in "Wetland", below.	The maximum delta-T of 2.8°C must be met continuously, not as an average. No cooling tower system can guarantee compliance with that maximum at all times, particularly during sudden weather changes. The recirculation system would come closer to meeting the delta-T regulation than the once-through system because it is designed for a closer approach to ambient wet bulb temperature. This is achieved, however, at a much higher investment cost with greater system complexity. None of the recirculating systems presently being evaluated include blowdown cooling facilities. Blowdown temperatures from these recirculating systems is expected to be lower (due to two cooling towers in series) than those which occur at steam-electric generating plants for comparable ambient conditions. Therefore, blowdown cooling systems used by those plants would not be as effective for SRP systems. The DEIS discussed the discharge of total suspended solids and sedimentation rates in the delta areas in Chapter 4. Discussions on water quality and hydrology summarized current conditions and changes expected with once-through and recirculating systems. The maximum flow rate discharged from a once-through cooling tower would be 11.3 cubic meters per second, which is the same as existing conditions. There would be minimal reduction in the total suspended solids from existing conditions. The discharge flow rate from a recirculating

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
		system would be about 0.51 to 0.57 cubic meter per second due to blowdown. The total suspended solids that would be discharged with the recirculating system would be greatly reduced because the intake flow of Savannah River water for this alternative is much less than for the once-through system. All discharges would comply with NPDES permit requirements and State Class B water classification standards.
BC-11	Although discussion to this point has centered on reactor discharges, the D-Area power plant preferred cooling alternative apparently will also require a 316(a) variance. Pumping of excess water for thermal pollution control is not normally accepted practice due to impingement and entrainment impacts and other factors. In this case, however, pumping to maintain the 32.2°C maximum thermal criterion of the South Carolina Water Quality Standards would appear to be the preferred alternative. Pumping during other periods should be minimized consistent with maintaining temperature patterns demonstrated to be acceptable for the protection and propagation of the aquatic community. In order to demonstrate the appropriateness of a variance and the establishment of appropriate discharge temperatures, it is suggested that DOE prepare a proposed plan of pump operation as a function of discharge temperature and month of the year as it relates to the life stages of the aquatic community.	See response to comment BB-5.
BC-12	The biological data necessary to support any required 316(a) variance request as well as the Habitat Evaluation Procedure (HEP) analysis should be documented in the FEIS.	See response to comments BB-3, BB-5, and BC-3.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	<u>Additional Alternatives</u>	
BC-13	Although only two alternatives for reactor cooling were proposed in the DEIS, variations to those might be considered. Since the presently proposed closed-cycle series tower design appears to be capable of compliance with all SCWQS thermal criteria, use of these towers in helper mode or in partial recycle mode (i.e., with some recycle of cooling water to the reactor to reduce discharge flow relative to helper mode) may reduce aquatic impacts.	See discussion of the recirculating cooling tower alternative in Chapter 2 of the FEIS.
	<u>Thermal Performance</u>	
BC-14	Based on EPA experience with existing cooling tower performance at steam electric power generating facilities, the following items are presented for DOE consideration in the design of cooling towers for the SRP site. Calculation of helper tower discharge temperatures based on direct use of closed-cycle cooling tower performance curves is not appropriate since the discharge temperatures computed are low. This is due to the fact that recirculation of cooling water produces a build-up of heat in the cooling system and higher tower inlet temperatures relative to the design wet bulb temperature. Higher tower inlet temperatures produce a greater driving force for tower cooling which is incorporated in standard performance curves for closed-cycle towers. Available information has been provided to DOE to allow recomputation of helper tower discharge temperatures, if necessary.	In addition to the following see also response to comment BC-4. Performance curves used in the engineering evaluations were provided by cooling-tower vendors and reviewed by the consultant. Engineering evaluation studies were continued for the recirculating system alternatives after the draft EIS was issued. Estimated blowdown temperatures were calculated for the recirculating system described in Chapter 2 of the DEIS and for additional alternatives. The evaluation included estimating temperatures following reactor shutdown, including total loss of electrical power. The maximum flow of cooling water from a reactor to a cooling tower is 11.3 cubic meters per second. For short shutdowns, the flow is 3.3 cubic meters per second, but for long shutdowns the flow is reduced to 0.63 to 1.3 cubic meters per second. Following

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
		shutdown of the reactor, the temperature of the cooling water discharged from the reactor heat exchangers rapidly decreases in 100 seconds after shutdown and approaches 32.2°C in 300 to 400 seconds after shutdown. The attached figure shows cooling water discharge temperature (water entering the cooling tower) following a reactor shutdown (scram). The temperatures shown are with a river water inlet temperature of 27.8°C, the approximate river water temperature in July. Although not shown on the figure, data obtained during the study showed that the reactor effluent temperature is within 1.1°C of reactor influent temperature 24 hours after shutdown. The temperature of the water in a recirculating system would rapidly decrease as the tower rejected the heat remaining in the recirculating system. Reactor heat would decline in a manner and time frame similar to that shown on the cooling water figure. The once-through cooling towers are bypassed only when the reactor is down. On recirculating system towers some maintenance can be completed while the tower is in operation. For maintenance requiring an empty system, near ambient temperature water (less than 32.2°C) would be discharged to the stream when the reactor is down.

Table J-2. DOE responses to comments on Draft EIS (continued)

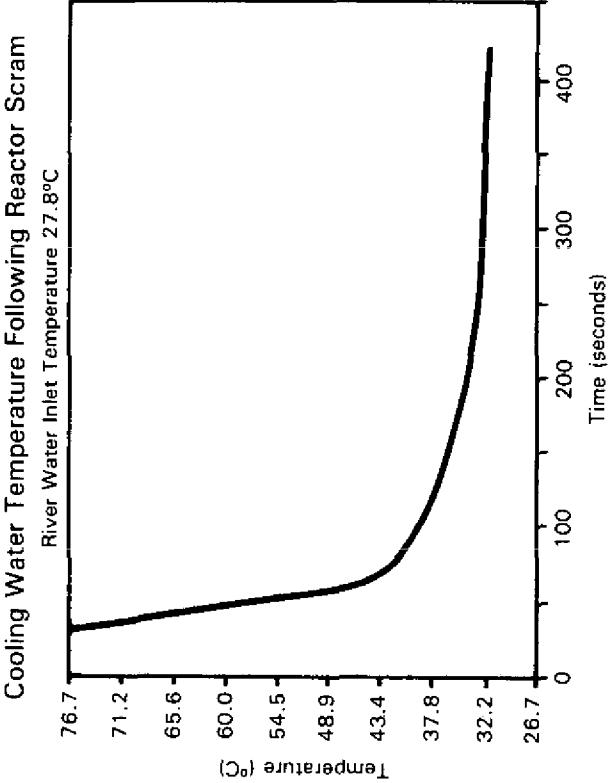
Comment number	Comments	Responses
BC-15	Cooling Water Temperature Following Reactor Scram  Environmental Systems Corporation has reported (see Attachment A): "Based on data acquired by Environmental Systems Corporation from their own acceptance and performance tests of over twenty coolant discharges. A consultant was	An estimate of cooling performance with deficient design was addressed for the type systems being considered for SRP reactor coolant discharges.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	fossil and nuclear power plant closed-cycle cooling systems, as well as data from contributing electrical utilities, cooling tower capability averaged 85 percent. The lowest of these was 76 percent while the highest was 99 percent." They further concluded that "this translates into roughly 3°F above higher return water temperature..." Should the towers proposed for SRP (either helper or closed-cycle) achieve only 85 percent of design capability, discharge temperatures of more than 3°F above the present estimates would probably result due to the higher inlet temperatures which occur at SRP compared to utility condensers. Unless flexibility is included in the tower design, once constructed it is seldom possible to significantly increase thermal performance. It is to be noted that where actual tower capability is less than design in a closed-cycle tower system, the owner suffers economic penalties due to lower production caused by the higher cooling water temperatures. However, in a helper tower system, only the environment suffers unless the production rate is reduced. It is therefore suggested that in addition to presentation of information for the 100 percent tower capability case, thermal data and biological data presented in the FEIS be based on a tower capability of 85 percent of design unless persuasive information can be provided as to why these conditions are not applicable to SRP.	hired to estimate the performance of the natural-draft cooling tower needed if it operates at 10 percent deficiency. The natural-draft cooling tower would be designed for: 1. Startup of the tower with 54.5°C inlet hot water temperature (HWT) with discharge cold water temperature of 32.2°C or less. 2. With reactor operating, 76.7°C inlet hot water temperature and approximately 31.1°C discharge cold water temperature. 3. 27.8°C wet bulb temperature (WBT) based on historical data and return-on-investment considerations to reduce reactor shutdowns caused by discharge temperatures being higher than 32.2°C, and 4. 40 percent relative humidity (RH). If this tower has a 90-percent thermal capability, the consultant estimates the following: 1. During startup of the tower when inlet water temperature reaches 54.5°C, tower discharge temperature (to tower basin) a. 32.8°C if wet bulb temperature is 27.8°C b. 32.4°C if wet bulb temperature is 27.2°C

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
		2. When the reactor is operating in the summer and the inlet temperature to the tower reaches 76.7°C, the tower discharge temperature is a. 31.7°C if wet bulb temperature is 27.8°C, or b. 31.1°C if wet bulb temperature is 27.2°C. 3. In winter operation the cold water temperature increase would be about 1° to 2°C for 90-percent capability at 50°C wet bulb temperature.
	<u>Cooling Tower Chemistry</u>	
BC-16	The type and management of the biocide and any corrosion inhibiting compounds being considered for the cooling alternatives is an important factor necessary for assessing the overall environmental impacts on the aquatic ecosystem. This is an area that was not adequately addressed in the DEIS and should be presented in detail in the FEIS.	See responses to comments BB-1 and BB-2.
BC-17	The FEIS should discuss the biocide alternatives being considered, expected effluent concentrations and durations, associated environmental impacts, and any plans for treatment and control. If chlorination is planned, the FEIS should address the specific steps that will be taken to ensure that the SC toxicity criteria for total residual chlorine will be met. Dechlorination should be discussed in the FEIS.	See responses to comments BB-1 and BB-2.
BC-18	It is possible that in a recirculated cooling system with the high reactor temperatures and recycled water chemistry involved, corrosion of reactor cooling piping will be a more significant	See response to comment BB-2.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	problem than postulated and will require the use of high levels of chromium or other toxic corrosion inhibitors. The addition of these chemicals could require chemical treatment of blowdown prior to discharge. Thorough evaluation of this situation at SRP should be made in the FEIS with the information provided and a comparative assessment made relative to the cooling water system materials of construction as they relate to the blowdown water treatment provided at the Oak Ridge, Tennessee and Paducah, Kentucky DOE facilities.	
	<u>Wetland</u>	
	Current operations of the C- and K-Reactor have resulted in approximately 1827 acres of wetlands being impacted by thermal discharges high flow rates and the resultant sedimentation and growth of the stream deltas. D-Area operations has impacted 382 acres of wetlands.	
BC-19	Helper cooling would reduce wetland losses due to thermal discharges downstream from the C- and K-Reactor, however, reestablishment of vegetation <i>would be limited because of continued high and fluctuating flow rates and the accompanying sedimentation.</i> The high silt levels continue to build deltas in the swamps at the mouths of the receiving streams. This high level of sedimentation continues to remove aquatic habitat and adversely impact the environment and therefore should be reduced. The closed-cycle cooling system alternative would restore flows to near natural levels and greatly reduce the level of suspended solids. Successional revegetation to bottomland hardwoods would be expected of 1500 of the impacted acres for the C- and K-Reactor and for a major percentage of the D-Area impacted acreage.	Operational impacts to the wetland community are addressed in Chapter 4, Appendix C, and Appendix F of this Final EIS.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
<u>Aquatic Habitat</u>		
BC-20	By reducing the temperature to within the 32.2°C criterion, both the helper and the closed-cycle cooling alternatives would significantly reduce the thermal impacts on the on-site streams and the Savannah River swamp. However, exceedances of the 2.8°C temperature increase criterion by the presently proposed helper cooling system (in addition to preventing the reproduction of fish as previously noted) may not permit the establishment of a stable aquatic community. This is a factor that must be considered in any 316(a) demonstration performed by DOE that assesses either helper or partially recycled cooling. The closed-cycle cooling system, however, would produce flows more nearly approaching natural levels in the impacted streams and thus permit the reestablishment of a more stable and diverse aquatic community. Spawning conditions for indigenous fish species would improve and there would be much less potential for cold shock from winter reactor shutdown. Because of the decreased flow rates of the closed-cycle alternative, stream sedimentation and changes in the stream morphology would be reduced proportionately, thus resulting in a more stable and healthy aquatic habitat. In addition, since the closed-cycle cooling water system decreases the raw water intake from the River, there would be a reduction in both the level of entrainment and impingement losses by as much as 85 percent.	See responses to comments 8B-3 and BB-5.
<u>Air Quality</u>		
BC-21	Air quality concerns exist for possible health effects of any releases of chromium if used as a corrosion inhibitor in the cooling system.	Design of cooling towers will include an allowance for injection of a corrosion inhibitor if needed. A non-chromated,

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	Although this is a relatively new area, research is underway by EPA at the Research Triangle Park to develop a model and determine potential health risks (A point of contact has been provided on the study). DOE should address the possible problems of using chromium in those alternatives where applicable (the results should be incorporated into the FEIS). <u>Radiological</u>	organic-based chemical made by Wright Chemical Company would be used. This chemical is approved by SCDHEC for use in cooling tower systems and is presently being used at the Savannah River Plant.
BC-22	Only very small differences exist among the alternatives in radiological activity with the amount of release not being affected, just the pathway (with a slight decrease for liquid releases and a slight increase for the atmospheric pathway). Slight changes in the radiocesium transport would result from the differences in release rates into the streams. The recirculating cooling alternative would result in 0.4 curies (Ci) reduction in cesium release for the C-Reactor and 0.6 Ci for the K-Reactor over the existing and helper cooling systems. <u>Construction Impacts</u>	The operation of the recirculating alternative would reduce flows in both Pen Branch (K-Reactor) and Four Mile Creek (C-Reactor), resulting in a calculated decrease in the cesium released to the Savannah River of 0.12 curie per year for Pen Branch and 0.21 curie per year for Four Mile Creek.
BC-23	Best Management Practices should be followed during all construction activities. The FEIS should address the following pre-construction and construction related impacts: • Point Source Discharges - sanitary, concrete mixing plant, etc.; • Solid Waste Management - clearing debris; • Other construction related water quality impacts - oil and hazardous substances spill prevention, and use of herbicides, insecticides, etc.; and • The use of erosion and sedimentation control measures such as - silt fences, sedimentation ponds and early revegetation of disturbed areas.	Best management practices would be followed during all construction activities. In addition, impacts of construction are addressed more completely in Chapter 4 of the FEIS.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
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TIN P2-1954
Attachment A

FLORIDA POWER CORPORATION
ANCLOTE SITE
CIRCULAR MECHANICAL DRAFT COOLING TOWER
THERMAL ACCEPTANCE TEST

PREPARED FOR:

FLORIDA POWER CORPORATION

BY:

ENVIRONMENTAL SYSTEMS CORPORATION
200 TECH CENTER DRIVE
KNOXVILLE, TENNESSEE 37912

JUNE, 1982

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	COOLING TOWER TEST FACILITY PROGRAM ESTIMATE OF THE ECONOMIC IMPACT OF DEFICIENT COOLING TOWERS	
	The performance of a power plant with a closed-cycle cooling system is intimately tied to the performance of the cooling system, especially during demanding meteorological conditions. If the cooling system is deficient, the condenser back pressure will be higher than design and the plant heat rate will increase. Capacity and energy penalties can be sizeable depending on unit design and the degree of inefficiency of the system.	
	Based on data acquired by Environmental Systems Corporation from their own acceptance and performance tests on over twenty fossil and nuclear power plant closed-cycle cooling systems, as well as data from contributing electrical utilities, cooling tower capabilities averaged 85 percent. The lowest of these was 76 percent while the highest was 99 percent. (As a point of interest, although not included in the subsequent economic analyses, four cooling towers tested at a geothermal installation averaged 87% capability, ranging from 70% to 95%). The majority of these tests were conducted on towers that have been operating for less than two years. Older cooling equipment, if not properly maintained, could be expected to have lower capabilities.	
	With this background, an estimate of the economic impact of deficient cooling towers follows. This technique is similar to that included in EPA-600/7-79-001 "Closed Cycle Cooling Systems for Steam Electric Power Plants: A State of the Art Manual." The megawatt ratings of existing and proposed plants with cooling towers were obtained	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	from the METER (Meteorological Effects of Thermal Energy Releases) computer inventory, which was part of an Oak Ridge National Laboratory study performed by Miller and Patrinos. There is assumed to be approximately 250,000 Mwe of fossil plants and 20,000 Mwe of nuclear plants serviced by cooling towers. If the cooling towers servicing these units are operating at 85 percent capability, this translates into roughly 3°F higher return water temperature to the condenser and attendant higher turbine exhaust pressures. In many cases, not only is unit heat rate increased, but during the more demanding summer meteorology, the unit is forced to reduce load to avoid higher-than-design turbine back pressures. The economic assessment, consisting of three parts, follows:	
	1. Replacement Capacity Penalty (P_1)	
	$P_1 = k \times FCR \times \Delta kw$	
	where:	
	P_1 = Capacity penalty in dollars	
	k = Replacement capacity rate, \$/kw	
	FCR = Annual fixed charge rate	
	Δkw = Loss of capacity due to the deficient cooling system	
	Assuming a total 100 units with 3 Mwe reduction each, and applying constants derived from recent utility data,	
	$P_1 = (\$500/\text{kw}) \times (0.2) \times (300,000 \text{ kw}) = \$30,000,000.$	

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
STATEMENT OF BRUCE BLANCHARD		
United States Department of the Interior Office of the Secretary Washington, D.C. 20240 ER 86/552 June 30, 1986 Mr. R. P. Whitfield Director, Environmental Division U.S. Department of Energy Savannah River Operations Office P.O. Box A Aiken, South Carolina 29802 Dear Mr. Whitfield: The Department of the Interior has reviewed the draft environmental impact statement for Alternative Cooling Water Systems, Savannah River Plant, Aiken, County, South Carolina and has the following comments. <u>General</u>		
BD-1	We recognize that each of the action alternatives offers significant reductions of existing thermal impacts to the affected wetland systems. However, a key consideration that appears to have been underemphasized in the draft statement is the projected lifetime of the reactors and consequent need for cooling systems. This consideration should have major bearing on the selection of preferred alternatives that may represent the best long-term balance among costs, production efficiency, and environmental quality. In consideration of the information presented, it appears that the recirculating cooling tower	The costs of electrical usage, as well as maintenance and production losses, are based on the assumption that reactors continue to operate for 15 years after construction of a cooling tower(s). Also see response to comment BC-6.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	alternative would provide the best long-term advantage from a cost standpoint, as well as providing significant reductions in impingement and entrainment. However, the habitat effects of each alternative should be carefully assessed before the proposed action is finalized. <u>Alternatives</u>	
BD-2	We believe the proposal described in the draft statement offers significant benefits to fish and wildlife resources when compared to the existing No-Action condition. However, the final statement would be improved by the inclusion of a detailed long-term analysis of initial and operating costs, environmental effects, and production efficiency over the project lifetime for each alternative. The projected lifetime of the currently operating reactor systems or the likelihood of reactor replacement and long-term need for cooling systems should be factored into the analysis because the available information indicates that significant long-term differences in effects to fish and wildlife resources may exist between action alternatives, particularly in reference to the C- and K-Reactor action alternatives. We suggest long-term annual operating costs may favor the recirculating cooling tower systems after approximately 9-10 years of operation even though the once-through cooling tower systems may represent a lower initial cost. <u>Impacts to Wetlands</u>	Initial and operating expenses, along with production efficiency, have been included in Chapter 2 of this FEIS. Environmental effects for construction and operation have been analyzed extensively and results are included in Chapter 4 of this FEIS. Also see responses to comments BD-1 and BC-6. Comment noted on preference for recirculating cooling towers. See discussion in Chapters 2 and 4 for more detail on this alternative.
BD-3	Currently, annual forested wetland canopy losses of about 54 acres are occurring in response to thermal impact and increased flooding in the affected areas. The once-through cooling tower alternative	See response to comment BC-19.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	would decrease forest canopy loss while allowing some revegetation of thermally impacted wetlands. Approximately 1,500 acres of previously forested wetlands would continue to be maintained in a permanently flooded condition by the discharges of C- and K-Reactors. With termination of thermal effects, these flooded areas would be expected to provide habitat for aquatic fish and wildlife species if discharge fluctuations are not too severe. The recirculating tower alternative would result in termination of both thermal and flooding effects due to C- and K-Reactor operations. This alternative would allow for successional revegetation of approximately 1,500 acres of previously forested wetland habitats.	
BD-4	The Habitat Evaluation Procedures (HEP) analysis being conducted for the Department of Energy by the Savannah River Laboratory will provide the best way to adequately compare alternatives with respect to long-term habitat effects.	See response to comment BC-3.
	<u>Cumulative Impacts</u>	
BD-5	The final statement for the L-Reactor Restart Project (ER 83/1211) states that on a cumulative basis, including all Savannah River Plant water intakes, the total entrainment losses would be up to 19 percent of the fish eggs and larvae passing the intake canal annually. The final statement should address the combined effects of D-Area, C-, K-, and L-Reactor operation on impingement and entrainment. The total losses from all intakes is significant. Consideration should be given to the installation of recirculating towers to reduce cumulative impacts from entrainment losses.	Entrainment and impingement impacts have been addressed in Chapter 4 with supportive information provided in Appendix C of the FEIS.

Table J-2. DOE responses to comments on Draft EIS (continued)

Comment number	Comments	Responses
	We hope these comments will be helpful to you.	
	Sincerely,	
	Bruce Blanchard, Director Environmental Project Review	